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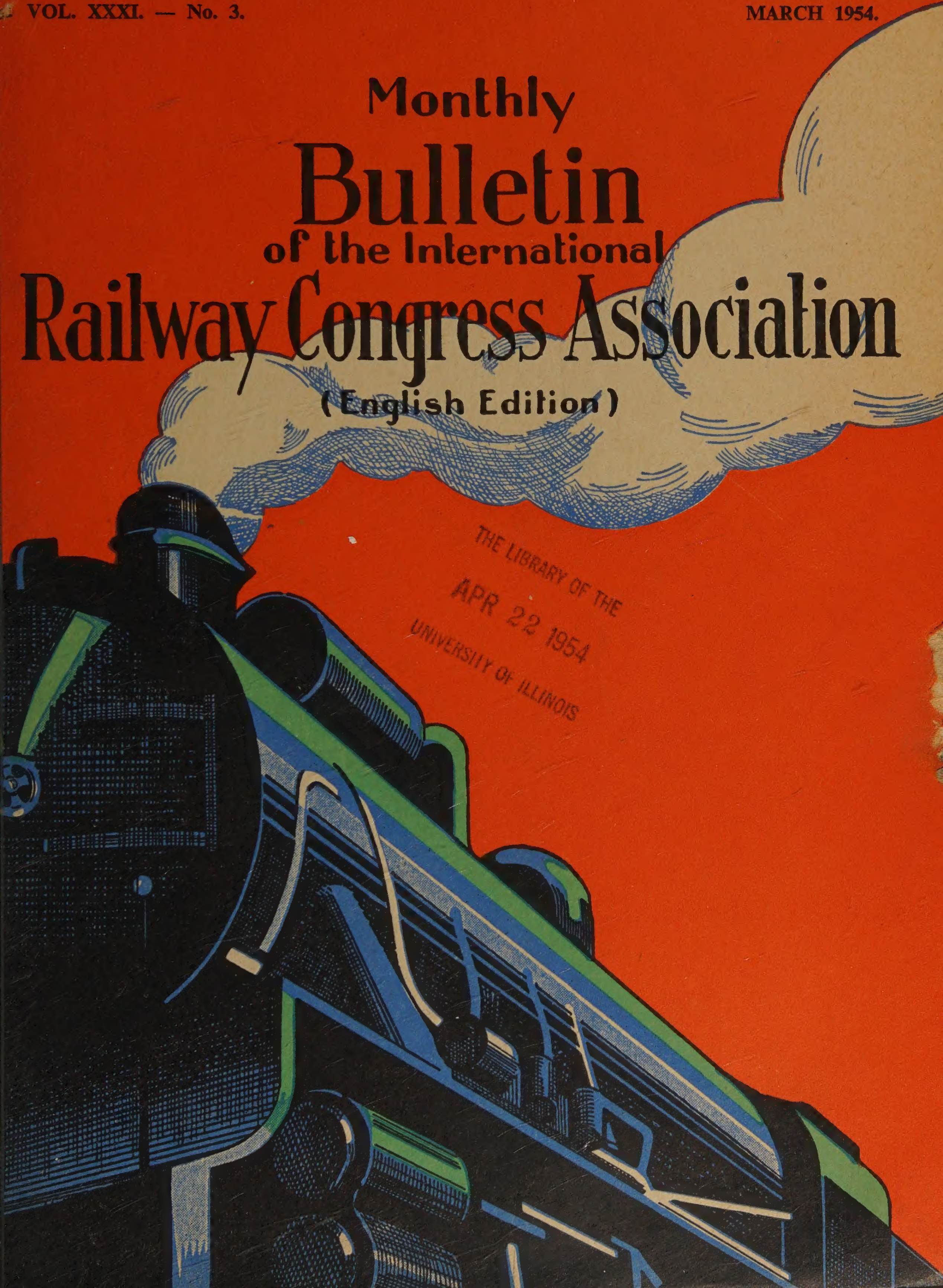
Monthly Bulletin of the International Railway Congress Association

(English Edition)



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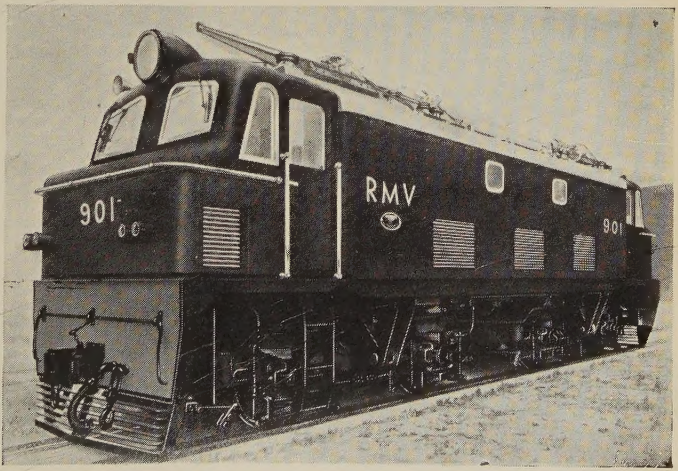

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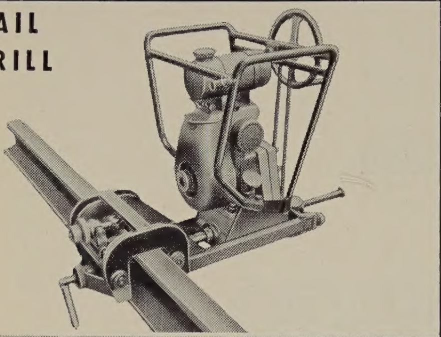

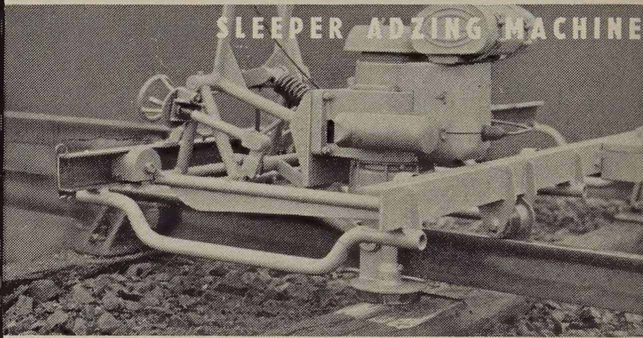

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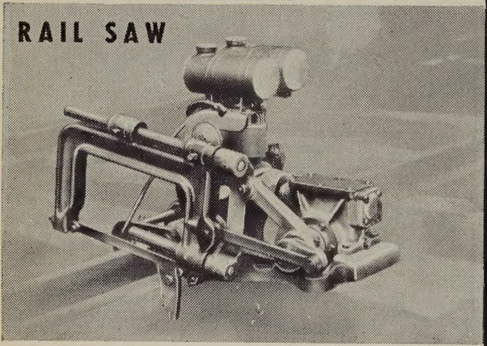

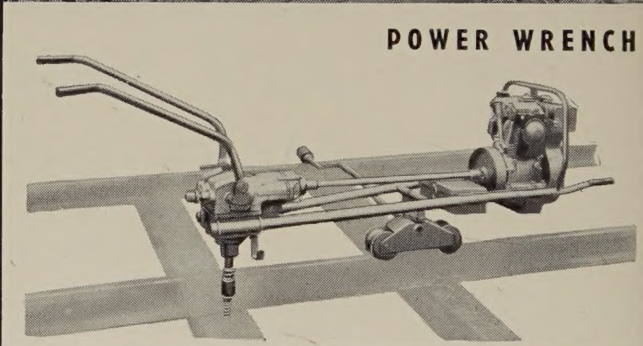

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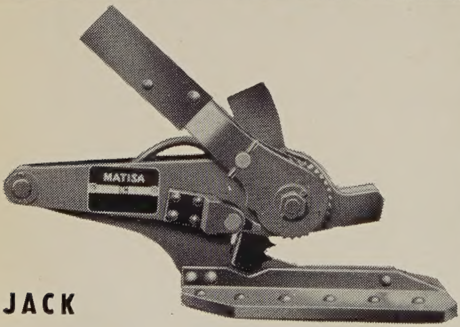

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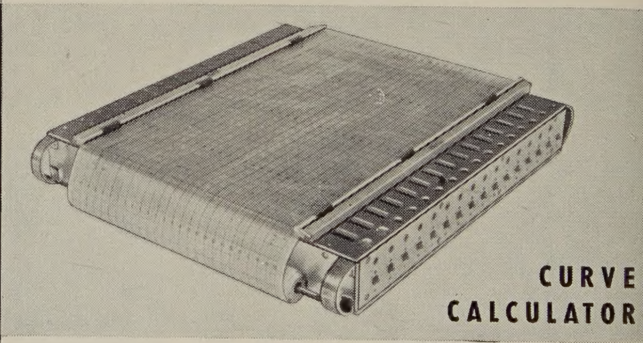

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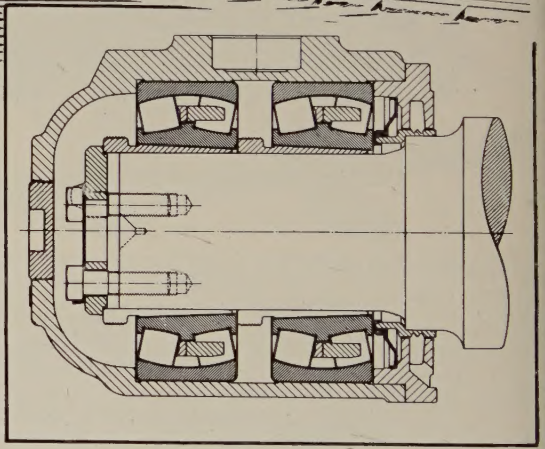

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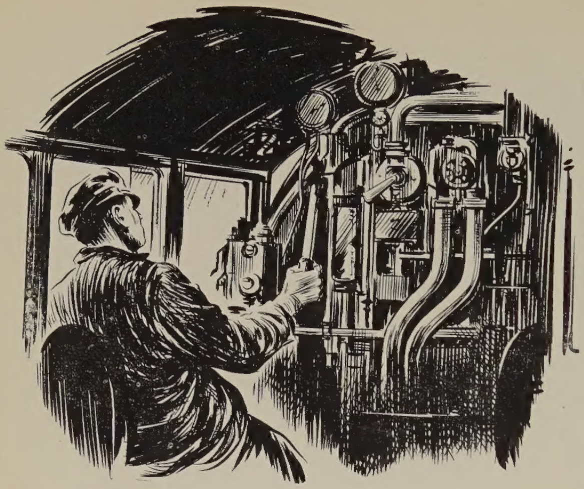

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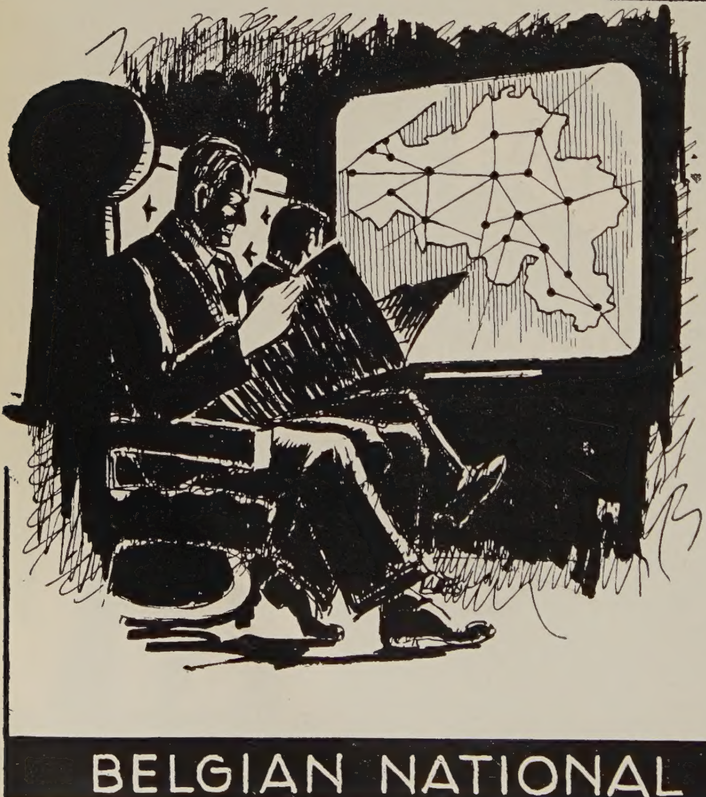

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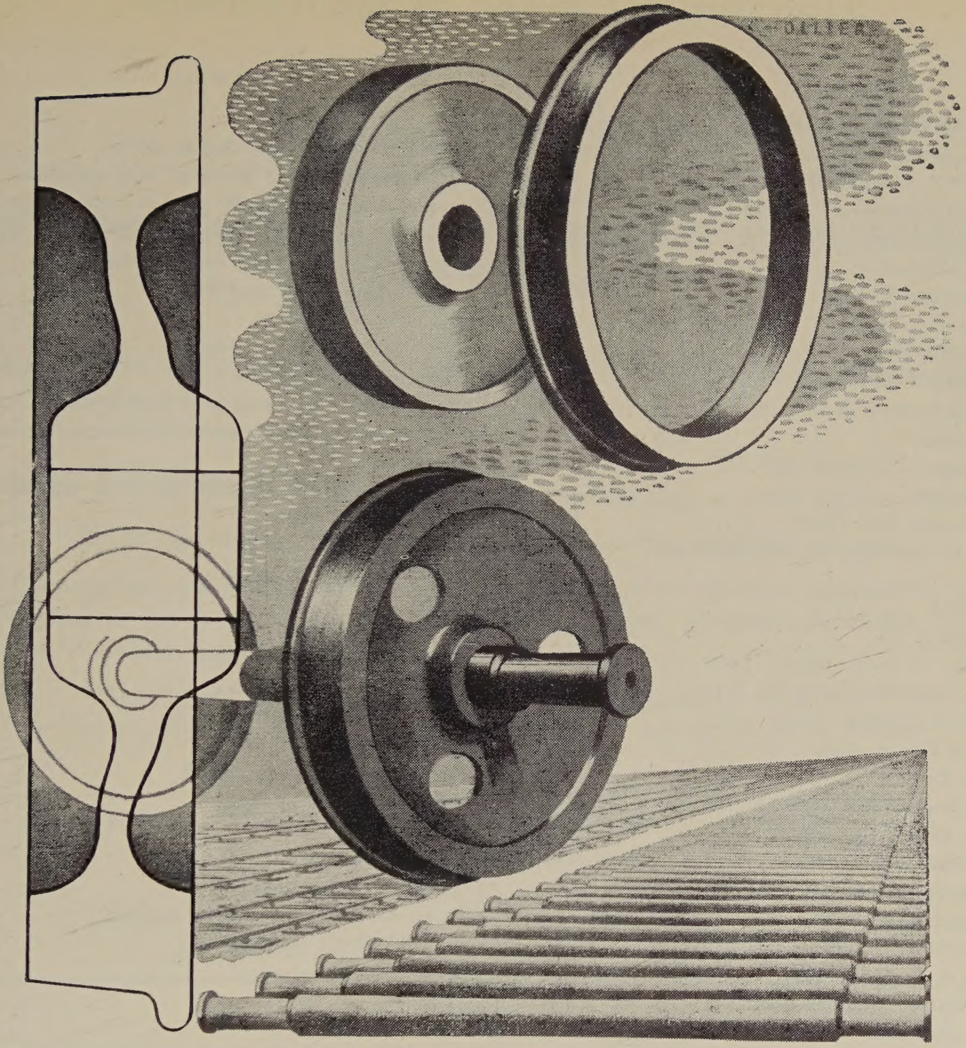

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MONTHLY BULLETIN
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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION
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Advertisements : All communications should be addressed to the Association, **19, rue du Beau-Site, Brussels.**

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An edition in French is also published.

Vol. XXXI. — No. 3. March 1954.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .17]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

16th SESSION (LONDON, 1954).

QUESTION 1.

What are the present tendencies relating to the organization of the maintenance of the permanent way: methods of determination of the works to be done and in particular, possibilities of the use of detecting-recording coaches, planning of the works, effects of mechanization; importance of the side-tracks for the movement of the gangs and the mechanical devices.

Economic and financial aspect.

REPORT

(Austria, Bulgaria, Czechoslovakia, Germany, Hungary, Poland, Rumania, and Yugoslavia),

by Dr.-Ing. habil. Gerhard SCHRAMM,
Referent für Oberbau bei der Hauptverwaltung der Deutschen Bundesbahn, Frankfurt (Main).

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service roads as only one-third of their length and each track unit for 0.1 km = 100 m of track. For the DB we thus get from the figures in Table 1 an extent of the system of :

$$n = 70\,300 \text{ km} \qquad (2)$$

In determining the extent of the system, other factors obviously could also be taken into account, for example the operating load on the various lines. This refinement would, however only complicate the question and make it more difficult.

The extent of the ÖBB system is n = 10 100 km, i.e. 14.4 % of the DB.

If it is desired to take into account the load on the system, we could take as a measure the gross hauled ton/km B. This figure covers the loads and tare weights of all vehicles except locomotives. On the DB :

$$B = 173.9 \text{ thousand million t/km} \qquad (3)$$

and for the ÖBB :

$$B = 19.2 \text{ thousand million t/km.}$$

Dividing the traffic by the extent of the system, for the DB.

$$\frac{B}{n} = \frac{173\,900\,000\,000}{70\,300} = 2\,474\,000 \text{ t}$$

and on the ÖBB :

$$\frac{B}{n} = \frac{19\,200\,000\,000}{10\,100} = 1\,901\,000 \text{ t.}$$

Load in relation to extent is therefore on the Austrian Federal Railways only 77 % of the DB. In appropriate cases, this fact must be reckoned with in making comparisons.

B. ORGANISATION OF TRACK MAINTENANCE.

1. Permanent way districts. (Bahnmeisterei.)

We will deal with the DB type of organisation. The track network to be maintained comprises a total of 71 500 km of track (not route) and 181 600 track apparatus units. The system is divided into 16 Regions (BD) (Bundesbahndirektion), so that each Region has on an average to maintain about 4 500 km of track and 11 300 track units. The various spheres of Regional responsibility are however of very different extents. For example the smallest Region has only 1 900 km of track and 3 500 track units, whilst the largest has 8 500 km of track and 20 600 track units. Taking into account the unit of track equipment for 0,1 km of track, the ratio between the smallest and largest is 1 : 5.1. Below the Regions are 173 *operating areas* (Betriebsamt), in which is vested the supervision of the operating and permanent way departments. Each Region, therefore, has an average of 11 operating areas (the smallest has 4 and the largest 17).

Supervision and maintenance of the whole of the fixed installations, including the track, is entrusted to districts which are subordinate to the operating areas. There are a total of 1 181 districts responsible for track. They are for the most part also charged with the maintenance of signalling installations, telecommunication line supports and buildings. In places where these installations are particularly concentrated, however, there are special signalling districts (74) telecommunications districts (15) and buildings districts (49). These will not be taken into account in the following remarks. In addition to the 1 181 track districts, there are also 73 mobile works trains, each with a staff of 80, which are regarded as self-contained establishments. The total number of all establishments directly concerned with permanent way work is thus increased to 1 181 + 73 = 1 254. Each Region thus comprises an average of 1 181/16 = 74 track districts, and each area covers 7 dealing with track work. All track maintenance personel are administrated and paid by the districts and the mobile units.

In addition to the districts and the works trains, there are the following establishments :

16 permanent way material depots;

2 track equipment depots;

12 new and replaced sleeper depots.

To the 73 mobile works trains can also be added 11 *permanent way instruction trains* (Oberbaulehrzüge), where prospective district foremen receive practical and theoretical instruction. These instruction trains have been a great success because they enable prospective gang foremen to be taken to particularly instructive sites, depots, etc. as well as to familiarise them with all track work.

The extent of track districts varies considerably. The sub-division of the system into districts is, so far, based on the following principles :

Normal length of route of a district :
20 km of double track main line (H_2), or
30 km of single track main line (H_1), or
25 km of double track secondary line (N_2), or
40 km of single track secondary line (N_1).

If we take the route (not track) lengths, in km, under the foregoing symbols, the normal extent of a district is :

$$H_2 = 2/3\ H_1 + 0.8\ N_2 + \frac{N_1}{2} = 20 \quad (4)$$

Other considerations must obviously be taken into account in delineating districts, number and size of stations and yards, number of track equipment units, and secondary lines. The progress of mechanisation and motorisation will allow the size of districts to be increased. The DB is at present studying the possibility of reducing the number of districts by about 20 %. In these conditions, it would then be necessary to replace, as a general guide in the second member of the above equation, the figure of 20 by 25.

2. Staff organisation in the districts.

The following two types of organisation are possible :

a) The district staff are occupied exclusively in track work (maintenance of track and other fixed installations).

From the point of view of track maintenance, this form of organisation is the best, because for all work commenced the same experienced staff is constantly available, and consequently the efficiency of the personnel is higher. There are only small alterations because of illness; moreover the staff occupied at a site can be recalled in the event of a serious accident. Operating and traffic departments have their own personnel, administered independently of the works staff, and cannot call on track maintenance staff.

b) The district staff are also used when needed on other special work, in other words the personnel constitute a pool on which other departments can draw to meet temporary additional needs in the event of fluctuations in the demand on them.

This type of organisation is convenient for the operating and traffic departments because in the event of any unforeseen needs, the required staff can be obtained by simply asking the district which is responsible for supplying them.

On the Austrian Federal Railways, organisation *b*) is in force. In its favour are not only operating considerations but also the questions of salaries and staff administration. In general, the staff endeavour to leave the permanent way service which is arduous and incomparably less well payed, in favour of the operating service with the eventual prospect of making a career as a staff official. As this constant change of staff is injurious to the economy of permanent way work, attempts are being made to improve the position of the permanent way workers from the point of view of working conditions, pay and prospects, so that they will be content to remain permanently on track work. On the DB, attempts are being made to achieve this end by creating a special grade of « lengthmen » (Gleisbauer), who have received special trade training and are paid accordingly. Despite the drawbacks to the track service, however, type *b*) organisation will necessarily have to be retained for the time being.

In the execution of permanent way work it is necessary to bear in mind atmospheric conditions and seasonal traffic variations. The most favourable time is the spring; summer is a little less favourable because of the heavier passenger traffic and the unfavourable effect of heat on the work. From October it is necessary severely to limit the work because generally heavier freight traffic is experienced at this time. These considerations apply to the DB. In the west and south, there is less limitation of time, because the milder climate allows permanent way work to be carried out even in winter. On the DB therefore, major works of the annual programme are undertaken as far as possible during the six months from March to August. Consequently the necessary total of permanent way staff fluctuates considerably from one end of the year to the other. To cater for these fluctuations, the following steps can be taken :

a) to transfer, as far as possible, to the autumn and winter months (September to February) the track work which can be done in this period; these are, amongst others, inspection, minor maintenance, checking of points, track equipment maintenance, staff instruction, etc.

b) to retain only a relatively small core of permanent staff and cover the increased summer demand by temporary staff engaged for the period during which authorised works are undertaken. This is the method at present used by the DB, but it is today no longer practicable because the DB staff has the benefit of guaranteed security of employment. When the Administration engages supplementary staff during the summer months, they therefore always risk being unable to dispense with them at the end of the work which would unbalance the plan of winter maintenance.

c) to cover the increased summer work by letting an appropriate part of the major track work to *contractors*. This is possible only when there are competent firms. It has the advantage of not placing any obstacle in the way of punctual execution of the work but on the other hand it is rather more costly.

On the territory of the DB, there is an adequate number of track contractors, and they cover exceptional staff needs during the summer by their means; annually an average of 20-25 % of all track work is undertaken by contractors.

d) to provide for local fluctuations in staff requirements by the use of works trains having a staff of about 80 specialised workmen with the necessary tools. These trains can quickly undertake track works of some importance in places where staff is lacking. Table 2 shows the use of permanent way staff on an average during 1952.

TABLE 2.

Use of track maintenance staff on the DB (1952).

Total staff of the department. .	77 731
Used by other departments (Operating, Traffic Motive Power, etc.)	28 916
Remainder	48 815
Employed in shops dealing with reconditioning, construction of new track, etc.	19 776
Remainder for actual track maintenance (including illness)	29 039
Contractor's staff	7 134
Total staff on track work . . .	36 173

This shows that of the total labour force administered by the districts, $100 \cdot \frac{29\,039}{77\,731} = 37.3\ \%$ only are occupied in track maintenance. This immediately shows that organisation of type *b*) imposes on the districts a considerable load of additional staff and related work (pay arrangements, etc.)

which are quite distinct from permanent way work. It is understandable that the permanent way department will make every effort to relieve the districts of this work and confine them to their real functions.

If we relate the figures in Table 2 to the extent of the system according to equation (2), $n = 70\,300$ km, we get for the whole of the personnel employed on track work (including contractors) on an average during 1952 per 100 km of track :

$$100 \cdot \frac{36\,173}{70\,300} = 51.4 \text{ men per 100 km.}$$

The proportion of contractors' staff was thus an annual average of $100 \cdot \frac{7\,134}{36\,173} =$ 19.7 % of the total staff. Because of financial restrictions, however, it was possible in 1952 to undertake only 65 % of the normal programme necessary to maintain the track in a manner consistent with safe working. In these circumstances, and assuming the same methods of work as in 1952, the normal total of staff should be :

$$A - \frac{51.4}{0.65} = 79 \text{ men per 100 km of extent} \qquad (5)$$

of these 50 to 65 would be railway staff and the remainder contractors. There were the former figures for the Reichsbahn. We shall see later the extent to which the normal figure in equation (5) can be reduced by intensive mechanisation of track work.

3. Supervision of the lines.

Crossings are served by gate-keepers or special crossing keepers (permanent staff) belonging to the districts. The track maintenance gangs provide only the reliefs necessary in case of leave or illness. The same applies to the ÖBB. On the DB there are 40 300 level crossings, 18 000 of which are provided with gates. The gates are serviced by a special staff, the districts providing only auxiliary labour.

Length examinations are done by district staff. By the provisions of the legal regulations for the Construction and Operation of Railways, lengths must be examined six times per week on main lines and three times on secondary lines. The DB is trying to get this reduced to 2 and 1 respectively. A total of 15 000 men are employed on track examination. The permanent crossing keepers mostly live in the cottages provided at level crossings where there are gates.

4. Journeys to sites.

The lines of a district are subdivided into 2 or 3 sections, in which staff undertake minor maintenance under the supervision of a competent foreman. For large works, it is necessary to combine several gangs, where necessary borrowed from nearby districts. This means longer journeys to the site. According to the distance and local conditions, these journeys may be by bicycle, motorised trolley or train. As regards major works, passenger trains are stopped as required to set down and take up staff.

Payment commences on arrival at site. Journey time is covered by a small allowance. There is a short meal break of half an hour only, so that men must eat on the site. For protection against rain, sectional sheds or tents are erected on the site. Special sheds for use as dormitories are not provided. If large works must be undertaken in remote places, where it is not possible to assemble a sufficient number of men from nearby districts, work trains are used. They are stabled in a yard near the site. If there is no road available for the purpose, a special siding may be put down and taken up again on completion of the work.

5. Mechanisation of track work.

Mechanisation of track work started with the development of internal combustion and light diesel engines. Between the two world wars, the DB provided and put into service the following machines :

Ballast rollers, for compacting the ballast;

Krupp motor tampers (compressed air tamping heads driven by two-stroke petrol motors);

Electric drivers for screwing on and unscrewing coach screws;

Rail saws;

Machines for planing rails, etc.

The electric current was provided by generators driven by petrol or diesel motors located on the track side. In addition, the DB on its own territory used 964 auto-discharge ballast wagons with a total capacity of 22 500 tons. These wagons provide considerable economies by quicker and cheaper discharge of the ballast on the line. In addition, several cranes (travelling jib cranes) are used for track work and laying of equipment.

Despite the use of these machines, manual labour is still largely preponderant.

A change has taken place since the last war. Because of financial stringency, the cause of which is known, the DB was quite unable to provide the money necessary for track maintenance. To arrest as far as possible, the increasing deterioration of the permanent way, it was necessary to seek the maximum efficiency from the means available. The only effective method was mechanisation. In addition to the small machines already mentioned, Scheuchzer-Matisa ballast screening and packing machines, built during the past 20 years, provided considerable economies. Their use is limited only by the fact that they require relatively long track occupation. The DB intends to use them as widely as possible and consequently to provide each Region with two tamping machines. Before long each Region will have in addition a ballast screener. Further small mechanical tampers of various types are being put into service in increasing numbers.

As it is impossible because of lack of money to lay a sufficient number of new sleepers, existing sleepers must be retained as long as possible, amongst other things by methodical dowelling of wooden sleepers, which is beneficial on 15-year old sleepers. Special dowelling gangs, equipped with millers, dowelling tools, drills and screw cutters undertake systematic dowelling of long sections of track on the DB.

Concrete sleepers have been used by the DB for 10 years and have increased following mechanisation. They have increased in value because of the shortage of timber and steel during and since the war. Since then, they have shown themselves so reliable and promise such economy in future, that they are becoming more and more recognised as normal equipment, more so since with welded rails they offer a better guarantee against warping than do wooden sleepers. Because of their considerable weight, about 230 kg, efforts have been made from the start to avoid manual handling and to transport and lay them by purely mechanical means. Several methods have been designed for this purpose. They permit the laying of track on concrete sleepers at a rate of more than 1 km a day, whilst the earlier rate of laying of 200 to 300 m was considered very high.

A measure of the state of mechanisation is given by dividing the horse power of all machines (including trolleys) by the number of track staff. This may include or exclude shop staff. On the DB the available power of machinery has now (Summer 1953) risen to :

For track and track equipment	36 600 HP
In permanent way shops. .	12 500 HP
Total	49 100 HP
In comparison :	
the number of permanent way staff dealing with track and equipment is	28 850 men
in permanent way shops. .	2 650 men
Total	31 500 men

Reckoning *all* staff and *all* machinery, the overall mechanisation index is :

$$m = \frac{49\,100}{31\,500} = 1.56 \text{ HP per man} \quad (6)$$

The mechanisation index for track work proper is :

$$m_g = \frac{36\,600}{28\,850} = 1.27 \text{ HP per man} \quad (7)$$

and for work in the shops :

$$m_l = \frac{12\,500}{2\,650} = 4.72 \text{ HP per man} \quad (8)$$

Another index of the state of mechanisation is obtained by dividing the amount of horse power available for work on the line by the extent of the system given in equation (2); this gives :

$$m_n = \frac{36\,600}{70\,300} = 0.52 \text{ HP per km} \quad (9)$$

We have no corresponding figures for the Austrian Railways. On the DB the values of m, m_g and m_n continue to increase consequent on progress of mechanisation. At the end of 1954, there will probably be available 52 500 HP for work on the line.

With the same amount of men as quoted above, there will be :

$$m = 2.06 \text{ HP per man} \quad (10)$$

and

$$m_g = 1.82 \text{ HP per man on the line} \quad (11)$$

and

$$m_n = 0.75 \text{ HP per km} \quad (12)$$

6. Effect of mechanisation on track work.

Increasing mechanisation cannot fail to influence the organisation of track maintenance. All the large machines (ballast cleaners, tampers, track-layers, etc.) require a compact and well drilled staff to give high efficiency, which must not be taken off for other work. Consequently, each tamping or cleaning machine is allocated a gang of men who are accommodated in vans. The use of these machines thus results in coherent work being more and more taken from the districts. The use of these machines is directly controlled by the Regions and Areas. Furthermore, because of the small number of men in each district, the execution of track work of some size necessitates grouping the staff from several districts within the boundary of the same area. The use of these *area gangs* (Amtsrotten) is controlled directly by the Area. For the transport of staff and tools a large number of trolleys is necessary. For certain special cases, use is made of cross-country road vehicles.

When mechanisation is thus fully extended, the districts are left with only minor maintenance of track and equipment and the remainder of their activities is limited to current inspection of track and equipment, the certification of work done by the mobile train units, the track gangs or the contractors. The districts will thus find themselves greatly relieved of work by mechanisation and the 20-25 % extension in district boundaries will be justifiable.

Mechanisation will affect the number of staff in the following manner. Instead of the figure already mentioned (equation 5) of 79 men per 100 km extent, it will be sufficient, after mechanisation, to have about :

$$A_1 = 0.8 \,.\, 79 = 63 \text{ men per 100 km of extent} \quad (13)$$

or if 20 % of the work is undertaken by contractors, 50 railway men and 13 contractors' men. Taking the track system of the DB, total mechanisation will thus effect an economy of about :

$$(79 - 63) \,.\, \frac{n}{100} = 16 \,.\, \frac{70\,300}{100} = 11\,250 \text{ working days.}$$

At present (Summer of 1953) the total staff is 63 per 100 km extent. This figure allows at present only 80 % of the normal programme to be done. With total mechanisation, the same number of workers would permit to carry out the normal programme (increased by 25 % as it will be necessary to undertake this in the future if it is intended to maintain full security of operation. This fact shows that on the DB mechanisation will not lead to the dismissal of staff. On the contrary, it will considerably increase efficiency with the same number of men.

C. DETERMINATION OF WORK TO BE DONE.

1. Distribution of track and track equipment from a technical point of view.

The following two methods of using track materials are possible :

a) new material is laid and remains in position until it is no longer usable, when it is taken up and sold as scrap;

b) new material is laid on heavily-loaded lines and remains there only so long as it maintains a satisfactory condition for severe conditions. It is then taken up, re-conditioned where necessary, and used on less important lines.

Method a). — With this method, new material only is used for *all* track, but for economic reasons material purchased for lightly-loaded lines is lighter and of appropriate quality. With regard to rails, the method is scarcely applicable, because it would not be economical to lay smaller rails and material on secondary lines of lower loading. On the other hand, the method *a*) is used by many Administrations for sleepers, for example by all the U.S.A. railways. In that country, the sleepers are so cheap in comparison with wages, that reconditioning and transfer to other lines is not worth while. *New* sleepers are laid even on secondary lines. On main lines, a good average road bed is obtained by renewal of a sufficient number of individual sleepers, the low spacing of sleepers, about 50 cm, practiced in the United States being an important factor in this method. In the conditions ruling in Europe, this method is not normally economical.

Method b). — This is known as progressive user (Stufenwirtschaft). It is economical and normal particularly where material is expensive in relation to wages, so that it is necessary to lengthen as much as possible the *average overall life* of track material. As far as possible only a *single* class of heavy material is purchased, and laid only on heavily loaded lines (preferably main lines carrying express trains); this is for track renewals. Material displaced at these renewals is re-used in lines of lesser importance and, in the same way, the old material recovered from the second class are in turn used again on lines of even less importance. This process thus entails several handlings of track material.

If we designate the quantity of materials to be renewed (in km of rail or in number of sleepers) as *e*, and *x* as the proportion of usable material recovered from the displacement, and *y* as the amount of material recovered by substitution, we get as the result of the renewal *e* and subsequent total substitution :

$$a = e \cdot \frac{x}{1 - y} \qquad (14)$$

For example, when renewing wooden sleepers on the DB, usable sleeper recovery is at present $x = 0.5$, and in substitutions $y = 0.3$. On wooden-sleepered lines, for a renewal of *e* sleepers, this gives :

$$a = e \cdot \frac{0.50}{1 - 0.30} = 0.71 \cdot e.$$

With progressive use, it is important to purchase and lay currently a number of new rails and sleepers so that the old rails and sleepers taken up are exactly enough to provide for the necessary substitutions. It is therefore necessary that the system should be sub-divided, taking into account the recovery of old materials and the average useful life of materials in track where new material is used. Careful investigation some 25 years ago led to the classification of track and equipment into 1st, 2nd and 3rd categories.

First class track is that on which *new* material is generally used (rails, fittings and sleepers). They comprise in the first place main line track carrying fast trains and some exceptionally heavily loaded freight trains as well as, to a lesser degree, heavily loaded avoiding lines and sidings in hump shunting yards.

Second class track is that for medium traffic and lower speed, for example main lines and avoiding lines not in the first classification. In these lines only recovered rails and fittings are used, and if possible only recovered sleepers.

Third class track covers all other lines. Old material only is used. The two tables below show the division of track on the DB from the permanent way angle and from an operating angle.

TABLE 3.

Classification of track and equipment on the DB from the permanent way view point.

	Track		Equipment	
	km	%	Units	%
First class	32 200	45	54 200	29.8
Second class	25 300	35.4	70 600	38.9
Third class	14 000	19.6	56 800	31.3
Total	71 500	100	181 600	100

TABLE 4.

Classification of track and equipment on the DB from the operating view point.

	Track		Equipment	
	km	%	Units	%
Main lines	44 300	62	58 600	32.2
Other lines	27 200	38	123 000	67.8
Total	71 500	100	181 600	100

2. Types of track work.

Work undertaken can be classified as follows :

a) Running lines :

1) track renewal (complete relaying, new material);

2) sleeper renewal
3) rail renewal (partial renewal);
4) ballast renewal

5) complete substitution (by recovered material);

6) substitution of sleepers } partial
7) substitution of rails } substitutions;
8) overhaul (replacement of part of the fittings, tarring of plugs, tamping of sleepers);
9) treatment of joints;
10) plugging of wooden sleepers in long sections;
11) minor maintenance.

Track renewal and maintenance is considered only when it is carried out over a continuous stretch of at least 100 m.

b) Track equipment :

12) track equipment renewal;
13) substitution of track equipment;
14) partial substitution (points);
15) overhaul;
16) minor maintenance.

3. Determination of work to be done.

For main lines, the DB has a « *Graphic state of the track* » with one strip per line (AzObv 2). This indicator contains information on gradient and curvature, age and condition of material, including ballast, load on the line, work done, etc. These graphic representations with local reports form a basis for deciding the work to be done on the line.

Track repairs were formerly carried out to a set plan, so that each main line was overhauled at fixed intervals, varying from 2 to 4 years. Shortage of labour and finance since the last war has prevented the continuance of this systematic repair. It is therefore no longer done methodically over long sections as formerly, but is restricted in each case to the sections where it appears absolutely necessary. It is often confined to adjustment of joints. To appreciate the need for work, reliance is placed not only on the graphic indication already mentioned, but also on :

a) the recorder rolls from track inspection vans;

b) the lengths walked or travelled by trolleys by the district foreman;

c) the guidance given by the Head of the permanent way department or the Region controller.

The DB track inspection van gives all measurements relative to level and alignment of track, particularly sinking of sleepers (low joints) on both lines of rails, gauge widening, relative level of the two lines of rails, and consequently the angles of superelevation slope, alignment of track (angular diagram) the versine curve (curvature) for the two sets of rails and for each line of rail, the presence of undulatory wear on the running surface.

The condition of sleepers (rotting of wood) and ballast are not recorded directly by the inspection van. An idea of this can however be obtained from interpretation of the recording roll, because poor condition of sleepers is usually reflected in bad joints and gauge clearance, and ballast defects by side oscillation. The principal roads of main lines are generally recorded every two years and main sections of secondary lines every three or four years by the inspection van. Sidings are not normally recorded. The recording van is usually hauled by a locomotive at a speed of 60 km (37 miles)/h.

District foremen cover the track at fixed periods on foot or by trolley, and note movements of locomotives. Area engineers, departmental officers and the Regional controller carry out tours of inspection to verify the need for major works reported by the districts.

4. Certification of track work.

Track work of a certain degree of importance (renewals, replacement of running line, renewal or replacement of major equipment) are usually certified by the Regional Controller, the Area engineer or his representative and the District foreman. The DB has published precise instructions regarding certification (AzObv 39). Alignment and level of track are recorded as far as possible by the track recording van or trolley. In addition, inspection is made of rail-gaps, road-bed, smoothness of joints, gauge, versines of curves, section of ballast, bedding of sleepers (by hammer), level of joints, tightness of fittings, side paths and drains, etc. The details and action required are recorded on a special form in accordance with AzObv 39 and the certification is recorded also on a form prescribed by AzObv 39.

For certification of work, it is immaterial whether the work has been done by a contractor or by railway staff (local or works train gangs). All track work of some importance undertaken by railway staff is done in accordance with capacity. Contract work is let by *restricted tender* between a certain number of firms.

D. METHODS ADOPTED.

1. Track laying.

In track renewal or replacement, all work is, as far as possible, undertaken simultaneously (changing or renewal of ballast, renewal or replacement of sleepers and rails) because this method is more economical than partial renewal or replacement.

a) *Laying concrete sleepers.*

Since concrete sleepers weigh some 230 kg or about twice as much as beech sleepers ready to lay, they are laid as far as possible by special machines (see chapter B, 5). This is the cheapest method of laying. It has been possible to organise single line working with one or two sets of points on electrified lines with a total load of about 200 trains a day (in both directions), cancelling or diverting a certain number of freight trains and replacing some passenger or workmen's trains by bus services.

Track sections of some length can, where necessary, be sub-divided into part sections so that single line working is only needed over shorter distances. This naturally means increased expense for installing points and signals.

If the line cannot be closed for the period of the work, the laying of track mechanically can still be done economically in intervals between operation of less than 5 hours. With shorter halts in operation, but not less than 3 hours, it is still possible to lay complete sections of track, assembled in a nearby yard and conveyed to the site on special lorries. This method is possible even with curved track. With it, it is possible to lay in a 3-hour interval between trains, 3 stretches of track of 60 m each.

If the traffic is too heavy to allow a stoppage of at least 3 hours, the new sleepers must be laid in the track by the Klotz method (Klotzverfahren). Speed must be reduced in this case to 40 km (25 miles)/h AzObv 18 contains exact instructions covering this method. The laying of sleepers by this method is rather more costly than wooden sleepers, because of their greater weight.

b) *Laying wooden sleepers.*

Wooden sleepers are as a general rule laid by hand. They are fitted with sole-plates at the impregnation depot and loaded on wagons, immediately after leaving the sole-plate fitting shop and distributed on the site along the track. Mechanical laying of wooden sleepers on a prepared stretch of ballast is not usually practicable because of the variable heights of the sleepers. On the other hand, the laying of complete sections of track as described above can be considered with wooden sleepers. This method has so far, however, only been used on a small scale.

c) *Laying of metal sleepers.*

Since 1938 the DB has no longer purchased new metal sleepers. As about 44 % of all DB track is still laid on metal sleepers, however, the recovery of these when renewing or replacing track is still so important that about 25 % of all sleepers laid (new and used) are metal. They are usually laid in moulds (AzObv 17). Metal sleepers are rather more costly to lay than wooden ones.

d) *Other work.*

All other work arising during relaying is now done as far as possible with mechanical aid.

For *ballast cleaning,* Scheuchzer-Matisa type machines have given excellent results. Efficiently used, they can undertake the average annual work of 80 men. The DB intends to put into service 16 of these machines.

New ballast is taken from the store to the site by *special auto-discharge wagons.* It is levelled by *caterpillar scrapers* and rammed by *ballast cylinders* or *Vibromax rammers.* The gravel layers under concrete are laid by special motor-driven machines. The rails are unloaded from wagons by special unloading gear and long 120 m welded rails for track to be welded are drawn from the end of the wagons by special inclined ramps. Tightening and releasing of coachscrews is done by electric tools supplied by generators, usually diesel-driven.

2. Tamping and packing.

For 30 years, mechanical tamping has gradually increased. Before the war, the DB used a considerable number of Krupp type *mechanical tampers.* Since then the *mobile mechanical tamper,* Scheuchzer Matisa type, has shown itself the most economical tamping machine for all types of sleeper. Efficiently used, they perform the average annual work of 35 men. The DB used 33 of these for a large part of the tamping work of track laying and repair. A disadvantage of the tamping machines is that they can only operate on a line closed to traffic. When the period of closure is restricted, their economic efficiency is reduced. Below half-an-hour, their use cannot be justified at all. In general, work with tamping machines is recommended when there are at least five intervals between traffic per day of one hour or more. If traffic does not allow this, it is necessary to use tamping machines which do not interfere with operation. In addition to the Krupp type machines, *Jackson* and *Losenhausen* (Vibromax) types have given good results and are largely used by the DB. In addition, *measured shovel packing* has been used for 10 years. This method however requires a well-settled ballast and cannot be used for track renewal and replacement.

The DB considers to do all fixing work in future by this method and manual shovel packing would be only used in exceptional cases.

3. Laying of track equipment.

Cranes have in the past been used to a limited extent for laying and lifting track equipment. This will in future be extended, because the use of cranes for laying track equipment has been found extremely economical. Twenty years ago, the DB built as an experiment a *track equipment wagon* for conveying complete assemblies from the workshops to the site. This vehicle, however, was too elaborate and its availability too restricted, and no subsequent vehicles have been acquired. The laying of track equipment is preferably entrusted to work trains, as it is in the installation of this type of equipment that a well organised and trained gang gives the most effective service.

4. Other maintenance work.

The remarks in section 2 above apply to tamping and packing. Because of the excessive age of wooden sleepers, resulting from the scarcity during the past 20 years, the DB is at present proceeding with a systematic dowelling of long continuous sections of track with 10 to 15 year old sleepers (see Chap. B, 5). By this means it is hoped to defer the withdrawal of the sleepers by several years. This work is done mechanically by specialist gangs using planers which smooth off the soleplate bed without having to remove the rails; and screwing and unscrewing machines for coachscrews and dowelling tools.

The DB attaches great importance to sleeper reconditioning. All displaced wood and metal sleepers still usable are carefully reconditioned; wooden sleepers by planing and plugging in *special sleeper depots*, and metal sleepers by welding of usable portions. By this means, about 70 metal sleepers are recovered out of every 100 lifted.

5. Machines and tools used by the DB.

Table 5 below shows the more important machines and tools which the DB will possess at the end of 1954. To allow comparison with other Administrations, we have shown in col. 4 the number of tools related to 1 000 km of extent in accordance with equation 2.

TABLE 5.

Machines and tools used by the DB for track work (end of 1954).

1	2	3	4
	TYPE	No A	No. a $= 1\,000 . \frac{A}{n}$
1	Ballast cleaning machines	16	0.23
2	Tamping machines	34	0.48
3	4-head mechanical tampers	450	6.40
4	Equipment for laying concrete sleepers	42	0.60
5	Swing jib cranes	35	0.50
6	Track laying cranes (gantries)	9	0.13
7	Equipment laying cranes	3	0.04
8	Levellers.	32	0.46
9	Vibromax ballast rammers.	72	1.02
10	Ballast cylinders	53	0.57
11	Packing machines (complete sets)	770	10.96
12	Planing tools (complete sets)	19	0.27
13	Trolleys	160	2.28
14	Auto-discharge ballast wagons	22 500 t	320 t

6. Safety precautions.

a) *Traffic safety precautions.*

The rules to be followed are contained in *Operating Regulations, Signalling Regulations* and the *Obv* (Chapter VIII). Every part of the track closed to traffic must be protected by protection stop signals even if it is beyond an entry or exit signal in the stop position. A telephone must be connected to the site. Where work affects the ballast (Klotz method), the speed must be restricted to 40 km (25 miles)/h. Moreover, the work must be so organised that a speed of 60 km (36 miles)/h would as far as possible be allowed. A road which has been closed to traffic must be opened for the first train at a speed of 40 km/h only.

b) *Protection of track gangs.*

The measures are contained in the *Instructions for the Prevention of Accidents, Operating Regulations, Signalling Regulations* and the *Obv* (Chapter VIII). Owing to the increased use of noisy machinery it is necessary to post more look-out men and the warning signals must be louder, if necessary by using compressed air horns (syrens) instead of the musical horn.

The points where the workmen can stand aside when the warning is sounded are marked by special white flags. In principle, a road under repair which is not closed to traffic must be cleared, even for a train on the next track. This means a serious loss of time on heavily-loaded lines; for this reason the DB has recently allowed men to remain on a line under repair where it is specially provided for when a train passes on the next track, subject to the weather being fine and clear. Work must however be stopped during the passing of a train.

For certain work (for example, mechanical tamping on a road not closed to traffic), the departure of each train must be communicated by telephone to the nearest operating staff in advance of the site. In certain other cases, the information is telephoned only in respect of special trains or those which do not run regularly.

When trains pass over a road in course of repair, the removal and replacement of screwing machines and mechanical tampers requires 1 or 2 minutes and planing tools 3 to 4 minutes.

In B. 6 above, we mentioned future effects of track work mechanisation on the organisation of track maintenance.

7. Importance of the side paths for maintenance work.

Foundations are made of a bed of clinker 10 to 15 cm thick to ensure good drainage of the formation and prevent the establishment of weeds. Figure 1, above, shows the normal section of ballast in accordance with the AzObv for a double track line, on the left, with wood sleepers; and on the right, with concrete sleepers. The width shown, 5 m, is a minimum, and the depth of the ballast 40 cm a maximum. Consequently, if the standard dimensions are observed, the side paths should have a width of at least 70 cm with wooden sleepers and at least 73 cm with concrete sleepers on lines without superelevation. On canted track, however, these widths are reduced and can fall to 26 cm with the permissible elevation of 15 cm. In this case, it means that the paths (fig. 1, hereafter) are reduced to 44 cm with wood sleepers and 47 cm with concrete sleepers. On track without superelevation, the side paths are symmetrical to the track centre line. On electrified lines, the contact line supports are usually located outside the paths, but where space is limited, they may be placed in the pathways.

The minimum widths of paths shown in figure 1 do not always exist in practice. On mountain lines in particular, the paths are often too narrow, either because smaller widths have been used in the construction of the line, or because track relaying has involved a widening of the bed of ballast and the sides have been made narrower in consequence.

Moreover, various obstacles (surface signalling wires, signals, mileposts, etc.) are found on the side paths or near them. In general, therefore, on the DB and ÖBB paths can be used only by persons on foot and in places for cycles. They permit the conveyance of tools and machinery only to a limited extent. In general these articles must be conveyed to the side *by the road*. On the German and Austrian Railways, it is only in exceptional circumstances that roads running alongside the permanent way belong to the railway. The same applies to public highways in the immediate vicinity of the line, which could be used for the transport of machinery and motors.

Bridges are normally wide enough to allow persons on foot to proceed without danger from any part of the track. On long, narrow bridges refuges are provided at intervals. Bridges are arranged only for crossing on foot and not by bicycle or other conveyance. Further, the sides are connected to the structures by short ramps or steps only. On many other Railways, for example in the U.S.A., there are almost everywhere wider side paths and even in addition to the paths private roads outside the permanent way limits, so that almost everywhere there is a means of access for relatively large equipment, tracked or road vehicles alongside the line. On the DB and ÖBB systems, the limits of railway property are often in the immediate vicinity of the line so that it is not possible to provide such favourable conditions. It is not generally possible to obtain any widening of paths for the transport of large machines alongside the track because of the considerable expense involved.

The DB however try at present to clear the side paths of all impediment and to widen them as much as possible in order to create, favourable conditions for conveying tools and machines and put them aside when needed.

Track on wooden sleepers. *Track on concrete sleepers.*

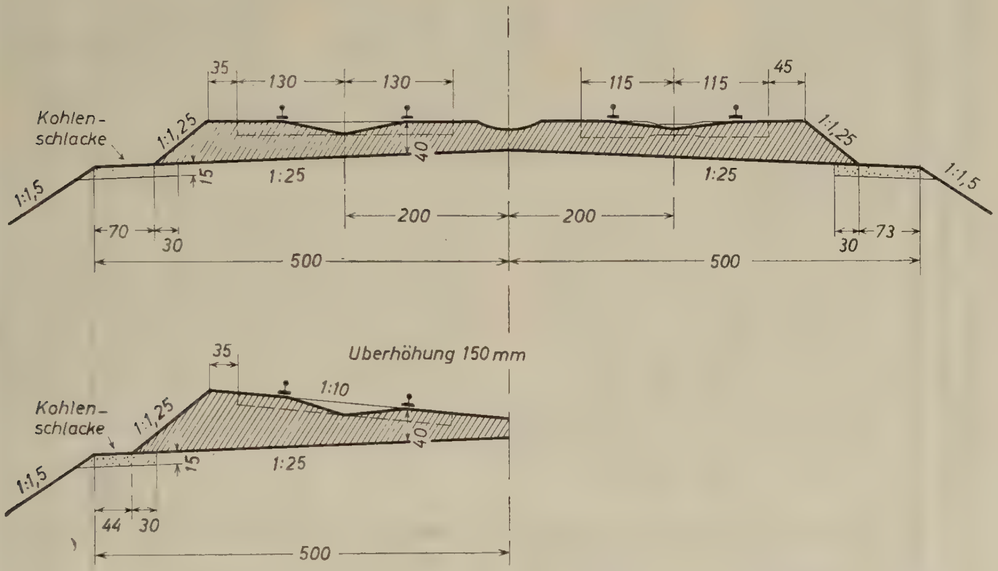

Fig. 1. — Normal section of ballast on the DB for double track line without superelevation (left, wood sleepers, and right, concrete sleepers), with the max. permissible superelevation of 150 mm (6″).

E ECONOMIC CONSIDERATIONS.

1. General.

For some years, the amounts actually spent by the DB on track maintenance have been considerably below the amount need-

TABLE 6.

Normal annual programme of track maintenance on the D.B., before total mechanisation (WE = units of track equipment).

1	2	3	4	5	6	7	8	9	10	11
Number	Type of work	km or WE	Steel	Sleepers	Ballast	Other materials	Reconditioning	Special items	Wages	Total
			Expenditure in million DM.							
1	Track renewal	1 300	94.21	43.81	8.32	2.88		10.40	31.68	191.30
2	Sleeper renewal.	500	10.04	16.96	3.20	0.85	1.28	4.00	9.27	45.60
3	Track equipment renewal	4 500	41.40	11.70	2.25	1.35		5.40	9.00	71.10
4	Ballast renewal	1 300			8.32				12.48	20.80
5	Track replacement . . .	1 300	6.00			5.02	19.54		16.14	46.70
6	Sleeper replacement. . .	400	1.61			1.66	3.45		4.28	11.00
7	Track equipm. replacement	4 300	5.80	1.85	1.38	1.29	5.59	5.16	6.88	27.95
8	Overhaul	14 400	3.97	2.98	3.74	5.44	2.90		57.60	76.63
9	Minor maintenance . .								23.92	23.92
10	Track workshops . . .								11.20	11.20
11	Snow clearance.								9.80	9.80
12	Various (look-out men, etc.).								14.00	14.00
Total			163.03	77.30	27.21	18.49	32.76	24.96	206 .25	550.00
In % of total			29.6	14.0	5.0	3.4	6.0	4.5	37.5	100

TABLE 7.

Normal annual programme of track maintenance on the DB. before total mechanisation, related to the extent of the system (70.300 km).

1	2	3	4	5	6	7	8	9	10	11
Number	Type of work	m/km or WE per 1 000 km	Steel	Sleepers	Ballast	Other materials	Reconditioning	Special items	Wages	Total
			Expenditure in D.M. per km extent.							
1	Track renewal	18.5	1 340.0	623.5	118.3	41.0		148.0	451.0	2 721.8
2	Sleeper renewal	7.1	142.8	241.2	45.5	12.1	18.2	56.9	131.8	648.5
3	Track equipment renewal	6.4	589.0	166.4	32.0	19.2		76.8	128.0	1 011.4
4	Ballast renewal	18.5			118.3				177.5	295.8
5	Track replacement . . .	18.5	85.4			71.4	278.0		229.6	664.4
6	Sleeper replacement . .	5.7	22.9			23.6	49.1		60.9	156.5
7	Track equipm. replacement	6.1	82.5	26.3	19.6	18.4	79.6	73.4	97.9	397.7
8	Overhaul	204.8	56.5	42.4	53.2	77.4	41.3		819.5	1 090.3
9	Minor maintenance . .								340.2	340.2
10	Track workshops . . .								159.4	159.4
11	Snow clearance.								139.4	139.4
12	Various (look-out men, etc.).								199.2	199.2
Total			2 319.1	1 099.8	386.9	263.1	466.2	355.1	2 934.4	7 824.6
In % of total			29.6	14.0	5.0	3.4	6.0	4.5	37.5	100

ed. For general comparisons between different railway administrations, which form a basis for discussion at International Railway Congresses, it is the normal expense which count, that is to say the *necessary* expense and not the reduced expense resulting from the financial difficulties of the administrations. We will therefore ignore the actual expenditure and consider the normal annual programme of work necessary to maintain the track in its present condition.

We shall not, however, deal with the supplementary expense which would be necessary if the DB were to bring its track back to the much higher standard it had before the war, in other words, we shall not take into account the direct or indirect damage caused by the war.

2. Normal programme of track maintenance.

Track maintenance is above all a question of material. Each year, as a result of operation, corrosion, rot, etc., there is a loss of track material. This loss can be completely made good currently, so that the system remains in its actual state and there is no substantial loss. The expenditure incurred in the purchase of new materials and their laying as well as the reconditioning and re-use of recovered materials constitute the major item of annual expenditure.

The amount of material to be replaced depends primarily on the total average life and this in turn is governed by the amount of traffic, the technical features of the system, its condition of maintenance, and the conditions it must satisfy. As regards the features of the system, the important factors are the type and average age of the rails, sleepers and fittings; number, type and average age of track equipment. For material used on the DB, it has been possible to establish by experience and careful study, the following average lives :

Sleepers	35 years
Rails	55 years
Track Equipment . . .	40 years
Fittings	35 years

These long periods of existence are achieved only by careful treatment and reconditioning of materials.

Until 1952, track work was mechanised only to a limited extent on the DB because war-time and post-war difficulties had not allowed any progress in this direction. *Table 6* gives the normal annual programme of the DB necessary for the permanent maintenance of safe operation in the 1952 state of mechanisation. Columns 4 to 11 show expenditure in DM millions. The « special items » in col. 9 include the work on signalling installations and other fixed installations related to the track maintenance programme (for example, connecting up track equipment, displacement of signals, modifications to platform sides, bridges, level crossings, etc.).

Table 7 shows the same programme related to the extent of the system, $n = 70\,300$ km, given by equation 2. Columns 4 to 11 show the expenditure in DM/km extent of system. These figures are directly comparable with corresponding values of other railway administrations.

The normal programme of tables 6 and 7 is based on the number of days, worked shown in table 8. This is the average for the year 1952.

3. Economies achieved by mechanisation.

As a result of mechanisation the number of day's work shown in table 8 have already been somewhat reduced in certain cases and they will continue to decrease until mechanisation is completed.

The DB has determined for the various machines the economies which they effect currently. In the following comparisons, all supplementary expenditure has been taken into account :

a) *Cleaning of ballast :*

by hand	12 480 DM/km
by Matisa machine .	4 100 DM/km
Saving	8 380 DM/km
average user . . .	78 km /annum
or a saving of . . .	654 000 DM/annum

TABLE 8.

Average number of days worked on the D.B. in 1952
(1 day's work = 8 hours)

1 km of track renewal on wood sleepers (with partial ballast renewal).	1 567 days work
1 km of track renewal on concrete sleepers (with partial ballast renewal)	1 329 »
1 km of sleeper renewal — wood sleepers	667 »
1 km of sleeper renewal — concrete sleepers.	615 »
1 unit of track equipment — renewal	118 »
1 km of track substitution on wood sleepers	759 »
1 km of track substitution on metal sleepers	771 »
1 km of sleeper substitution	657 »
1 unit of track equipment — substitution	88 »
1 km of complete renewal of ballast	801 »
1 km of partial renewal of ballast	527 »
1 km of 1st category track overhaul	272 »
1 km of 2nd category track overhaul	264 »
1 km of 3rd category track overhaul	325 »
1 km of minor maintenance of track	16.2 »
1 unit of track equipment — minor maintenance	3.1 »

b) *Matisa tamping machines :*

hand tamping . . .	4 900 DM/km
Matisa machine tamping	1 700 DM/km
Saving	3 200 DM/km
average user . . .	105 km /annum
or a saving of . . .	336 000 DM/annum

c) *Jackson or Losenhausen tamping machines :*

hand tamping . . .	4 900 DM/km
mechanical tamping .	3 460 DM/km
Saving	1 440 DM/km
average user of one set of tampers . .	11 km /annum
or a saving of . . .	15 840 DM/annum

d) *Concrete sleeper layer (type K1) :*

Saving . . . . 7 230 DM/annum for an average user of 25 km in 52 day's work. With greater user of the machine, the saving is more.

e) *Jib cranes (pivoting) :*

Saving . . . . 56 000 DM/annum for an average user of 75 % of the days worked.

f) *Gantry tracklayers :*

Saving of . . . 4 057 DM/annum (5 100 tons lifted in 45 day's work).

g) *Track equipment cranes :*

Saving of . . . . 59 000 DM/annum (12 300 tons lifted in 159 day's work).

h) *Leveller* :

by hand	1 380 DM/km
by machine	400 DM/km
Saving	980 DM/km

for an annual user of 82 km in 150 day's work,
or a saving of . . 80 400 DM/annum

i) *Vibromax ballast rammer* :

Saving . . . . . 13 000 DM/annum
for an annual user of 24 km in 150 day's work.

j) *Packing tools* (1 set) :

manual tamping .	4 900 DM/km
packing	3 970 DM/km
Saving	930 DM/km

One set of packing tools provides about 11 km in 200 day's work,
or a saving of . . . 10 230 DM/annum

k) *Plugging equipment* (1 set) :

economy by comparison with depot reconditioning is . . . 82 600 DM/annum

(annual production 13 km in 91 day's work).

From the above, the equipment *a*) to *k*) provides the following annual saving, taking into account the numbers shown in Table 5 and the annual user which experience has shown to be possible on the DB.

a) *Ballast cleaning machines*	16 . 0.657	10.51	million	DM
b) *Tamping machines* .	34 . 0.336	11.42	»	»
c) *Mechanical tampers.*	450 . 0.1584	7.13	»	»
d) *Concrete sleeper layers*	42 . 0.00723	0.30	»	»
e) *Pivoting jib cranes* .	35 . 0.056	1.96	»	»
f) *Gantry tracklayers* .	9 . 0.00475	0.04	»	»
g) *Track equipment cranes*	3 . 0.059	0.18	million	DM
h) *Levellers*	32 . 0.0804	2.57	»	»
i) *Vibromax rammers* .	72 . 0.013	0.94	»	»
j) *Packing tools* . . .	770 . 0.01023	7.88	»	»
k) *Plugging tools* .	19 . 0.0826	1.57	»	»
Annual saving . .		44.50	million	DM

Taking into account the extent of the system, an economy is obtained of :

$$\frac{44\,500\,000 \text{ DM}}{70\,300 \text{ km}} = 633 \text{ DM/km.}$$

By comparison with a maintenance programme undertaken without these machines, the saving is about 8 %. On the DB the total expenditure on track necessary annually could be reduced by mechanisation from 550 to about 505 million DM.

4. Other influences on economy.

a) *Interruptions due to traffic.*

During work which must be undertaken without interruption of operation, the number of days required increases because of the stoppages necessary as a result of the passage of trains. On the DB use is made of the percentages shown in Table 9 hereafter.

On time contract work, the number of hours are increased by these percentages. *(See Table 9.)*

b) *Displacement allowances.*

Staff occupied more than 3 hours outside their district receive a displacement allowance of 0.20 DM per hour or part thereof. Work train staff receive a daily allowance of 1.50 DM.

Because of increasing mechanisation, it is necessary to form area gangs in increasing numbers and accommodate staff in the work trains. In addition, the use of large

TABLE 9. —

Increase in the number of days needed related to the amount of traffic.

No. of trains per day on the line under repair	*Increase in the number of days required*
5 to 10 trains	5 %
11 to 20 trains	9 %
21 to 30 trains	13 %
31 to 40 trains	18 %
41 to 50 trains	22 %
51 to 60 trains	26 %
61 to 75 trains	30 %
76 to 90 trains	35 %

machines often calls for a specially trained and higher-paid staff. The average wages per man will thus be increased by mechanisation.

c) *Look-out men.*

Expenditure on look-out men cannot be shown as a fixed part of the cost of a days work because the position varies according to the nature and scope of the site. The use of large machines often makes it necessary to post an increased number of look-out men. At such sites, however, the number of look-out men is proportionately lower than on non-mechanised sites, the number of staff to be protected being considerable. Expenditure for this item will probably be reduced, on the average, with mechanisation. At present, however, there is no precise information.

5. Objects of mechanisation.

Manual methods will give a perfectly good and lasting road. It is even easier to obtain a high degree of accuracy in relative level of rails with hand tamping than with any kind of tamping machine. Mechanisation does not, therefore, improve the quality and durability of the work; it merely makes it lighter. Intervals between overhaul do not depend on the fact that the laying or previous overhaul was done mechanically or manually.

The DB, however, anticipates a saving in maintenance cost by increasing the periods between overhaul with concrete sleepers. The increased weight of the bedding and the jointless welding on concrete sleepers, which is widespread, will give a more durable level and alignment amongst other things, because of the elimination of joint maintenance which has so far represented a considerable proportion of the maintenance cost.

The saving in maintenance cost by concrete sleepering is assessed at about 20 %. Long experience alone will allow an exact figure to be arrived at.

It is impossible to say what effect concrete sleepers will have on track renewal expenditure. It appears from the experience so far gained by the DB and other Administrations that the life of concrete sleepers laid in first class track will exceed that of wood sleepers. The amount of the increase is, however, not yet known.

In Germany, wood sleepers were formerly lifted from 1st class track at the end of 15 to 20 years. Today, because of financial difficulties, they have to remain in use for 20 to 25 years and on removal not more than about 50 % of the recovered sleepers are re-usable. Careful investigations into economy have shown that the present prices of concrete sleepers compared with wood sleepers can be justified if the former attain a service in the track of about 35 years. With a longer period, the concrete sleeper would give compared with a wood sleeper, the following annual savings :

$$E = 105 - \frac{3\,663}{L} \qquad (15)$$

E being the annual saving in DM millions, L the life of concrete sleepers in years. For example, average lives of concrete sleepers of 50, 60 and 70 years would lead to economies of 32, 44 and 53 DM millions per annum respectively.

These considerations, and the continuous tendency towards welded rails have led the

DB to use large quantities of concrete sleepers. Despite this, wood sleepers will retain a certain importance, for example for track equipment and bridges, as well as numerous other cases where for special reasons concrete sleepers are not desirable. The ÖBB has so far laid only a small number of these sleepers for trial.

F. APPENDIX : TECHNICAL INFORMATION ON THE PERMANENT WAY.

We give hereafter some information on the type of permanent way for the DB and ÖBB, as being of general interest and of certain importance with regard to the preceding considerations.

1. Rails.

	Deutsche Bundesbahn	Osterreichische Bundesbahnen
Designation of standard rail	S 49	B
Weight	49 kg/m	(This rail is identical to the S49 rail)
Height	148 mm	
Width of base	125 mm	
Width of head	67 mm	
Thickness of web	14 mm	
Area of section	6 248 mm^2	
Moment of inertia (horizontal axis) . .	1 797 cm^4	
Modulus of inertia	239 cm^3	
Normal lengths	30 & 45 m or welded into continuous rail	15 and 30 m
Proportion of « Martin » steel	42 %	100 %
Proportion of « Thomas » steel	58 %	0 %
Normal tensile	70 kg/cm^2	70 to 75 kg/cm^2
Rails with high resistance to wear for special purposes	80 and 90 kg/cm^2	90 to 100 kg/cm^2
Protection against rust in tunnels.	Fittings galvanised, oil of creosote applied	Creosote oil applied
For what radius of track are rails curved beforehand ?	< 500 m	Rails not curved in advance
Are rails straightened at the depot? . . .	Yes by roller or ram machines	Same reply
Are rails finish-machined at the depots? .	Yes	Yes
Are old rails shortened by cutting the ends?.	Yes; all old rails are welded after use and cut into 35 or 45 m lengths	Yes
Are fittings reconditioned ?	Yes by private firms	Yes in works or by private firms
Average life of steel in track.	45 years (estimated)	45 years

For rails with a high resistance to wear, only naturally hard or special composition rails are used (see Table 10 hereafter) :

TABLE 10.

Chemical composition of normal and hard-wearing rails on the D.B.

Tensile	Type of steel	Percentages				
		C	Mn	Si	P	S
Normal rails 70 kg/mm²	Thomas	0.40 - 0.55	0.60 - 1.00	0.15 - 0.35	up to 0.08	up to 0.05
	Siemens-Martin	0.50 - 0.60	0.50 - 0.80	0.15 - 0.35	up to 0.06	up to 0.06
Semi-hard rails, 80 kg/mm²	Siemens-Martin	0.55 - 0.75	0.60 - 0.90	0.15 - 0.35	up to 0.06	up to 0.06
Hard rails, 90 kg/mm²	Siemens-Martin	0.64	1.57	0.30	0.029	0.021

The figures of the last line are from the Rheinhausen Forges. Other Forges have slightly different compositions.

In addition to the standard S49 rail, the DB have for some time used in tunnels a heavier rail, type S.64, having the following dimensions : weight 64.7 kg/m (142 lbs.); height 172 mm (6.73 in.); width of base 150 mm (5.90 in.); width of head, 74 mm (2.91 in.); thickness of web, 16 mm (0.629 in.); area of section, 8 241 mm² (12.77 sq. in.). This rail is laid without bed-plates; fixing is by coachscrews or Macbeth flexible fixings; it is usually welded into a continuous length through the whole of the tunnel.

2. Sleepers.

	Deutsche Bundesbahn	Österreichische Bundesbahnen
Purchase of sleepers :		
Concrete sleepers	60 to 70 %	trial only
Metal	0 %	22 % (only for track equipm.)
Wooden sleepers	30 to 40 %	78 %
Beech	64 %	36 %
Oak	6 %	
Resinous	30 %	64 %
Are all sleepers impregnated with creosote? .	Yes, in 16 private shops and 2 DB shops	Yes in private shops only
Are wood sleepers manufactured in railway shops?	Yes, all sleepers for equipment and a small proportion of plain track sleepers	No

	Deutsche Bundesbahn	Österreichische Bundesbahnen
Are old sleepers reconditioned in special shops?	Yes, in 7 DB old sleeper depots	Yes in small number in railway shops.
Are wood sleepers reconditioned in situ?	Yes	No
What proportion of recovered sleepers is re-used in the track?	50 %	20 %
What proportion of metal sleepers?	70 %	
What proportion of re-used sleepers is reconditioned?	100 %	Reconditioning in preparation
Are wood sleepers coated or impregnated with protective materials in the track?	Trials only so far	No
How do you repair old metal sleepers?	Electric butt welding of pieces	By deposit
Average life of :		
Concrete sleepers	Unknown	Unknown
Metal sleepers	45 years	35 to 45 years
Hardwood sleepers	40 years	17 to 20 years
Softwood sleepers	30 years	

3. Ballast.

	Deutsche Bundesbahn	Österreichische Bundesbahnen
Normal annual requirement of new ballast	3 million tons	0.5 million tons
ditto, related to extent of system	42.7 t/km	49.5 t/km
Granulation 1	30/65 mm 84 %	35/70 mm 78 %
Granulation 2	15/30 mm 8 %	25/35 mm 17 %
Granulation 3	10/22 mm 8 %	10/25 mm 5 %
Types of stone	Mainly basalt, porphyry and similar (no chalk)	Granite, dolomite, limestone, basalt, etc

4. Welding in permanent way.

	Deutsche Bundesbahn	Österreichische Bundesbahnen
Do you fabricate longer rails by butt welding?	Yes	Yes
With new rails?	Yes	Yes
With recovered rails?	Yes	Yes
Do you use electric fusion welding?	Yes	Yes
In your own shops?	Yes	Yes
In private shops?	Yes	Yes
Do you use the aluminothermic process?	Yes where electric welding is not convenient	Yes
With your own welding gangs?	Yes	Yes
By contractors?	No	Yes
What other welding processes do you use?	Gas welding for building up rails and equipment. Secheron welding on trial	Gas welding
To what length do you weld new rails?	30 m, 45 m and for welded track if possible 120 m	30 m
To what length do you weld recovered rails?	30 and 45 m	30 m and for narrow gauge, 20 m

[621 .33]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

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QUESTION 3.

Technical and economic investigation of the basic characteristics of electric traction systems now in use, with a view to decide whether, and to what extent, there are relevant reasons for preferring one system to another.

In particular, are there any reasons in regard to :

a) power supply;
b) overhead line and fixed track installations;
c) motive power units;
d) working and maintenance costs.

REPORT

(Austria, Belgium and Colony, Bulgaria, Czechoslovakia, France and French Union, Germany, Greece, Hungary, Italy, Luxemburg, Netherlands, Poland, Portugal and Colonies, Rumania, Spain, Switzerland, Syria, Turkey, and Yugoslavia),

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CHAPTER I.

INTRODUCTION.

1. — *Countries and Railway Administrations to whom the questionnaire was sent before compiling this report.*

With the object of having a concrete basis on which to plan the report on Question 3 on the agenda of the London Congress, a questionnaire was drawn up at a meeting, held in London, between the Reporters and the Secretariat of the Association. This questionnaire was sent to all the Railway Administrations concerned.

As far as the countries in question in this report are concerned, it was sent to the following Nations :

1) Austria, 2) Belgium and Colony, 3) Bulgaria, 4) Cambodia, 5) Czechoslovakia, 6) Denmark, 7) Finland, 8) France and French Union, 9) Germany (Western), 10) Greece, 11) Holland, 12) Hungary, 13) Indonesia, 14) Italy, 15) Jugoslavia, 16) Luxemburg, 17) Lybia, 18) Norway, 19) Poland, 20) Portugal and Colonies, 21) Rumania, 22) Spain, 23) Sweden, 24) Switzerland, 25) Syria, 26) Turkey, 27) Vietnam.

In the above mentioned countries, the following Railway Administrations were questioned :

AUSTRIA.

1) Oesterreichische Bundesbahnen.

BELGIUM AND COLONY.

2) Société Nat. des Chemins de fer belges.
3) Société Nat. des Chemins de fer Vicinaux.
4) Compagnie Générale d'Entreprises électriques et industrielles « Electrobel ».
5) Railways économiques de Liège-Seraing et Extensions.
6) Compagnie belge de Chemin de fer et d'Entreprises.
7) Chemin de fer du Bas-Congo au Katanga.
8) Chemin de fer du Congo Supérieur aux Grands Lacs Africains.
9) Chemins de fer Vicinaux du Congo.
10) Office d'Exploitation des Transports Coloniaux (Otraco).

BULGARIA.

11) State Railways and Harbours.

CZECHOSLOVAKIA.

12) State Railways.

FRANCE AND FRENCH UNION.

13) Société Nationale des Chemins de fer français.
14) Chemins de fer Départementaux.
15) Société Générale des Chemins de fer Economiques.
16) Chemins de fer Economiques du Nord.
17) Régie Autonome des Transports Parisiens.
18) Chemins de fer Secondaires du Nord-Est.
19) Compagnie Générale de Voies ferrées d'intérêt local.
20) Chemins de fer Algériens.
21) Chemin de fer de Gafsa.
22) Compagnie fermière des Chemins de fer Tunisiens.
23) Chemins de fer Royaux du Cambodge.
24) Chemins de fer de l'Afrique Equatoriale française et du Cameroun.
25) Chemins de fer coloniaux de l'Afrique occidentale française et Togo.
26) Chemin de fer franco-éthiopien de Djibouti à Addis-Abeba.
27) Chemins de fer de Madagascar.
28) Chemins de fer du Maroc.
29) Chemin de fer de la Méditerranée au Niger.
30) Chemins de fer coloniaux de l'Indochine.
31) Compagnie française des Chemins de fer de l'Indochine et du Yunnan.

GERMANY (Western).

32) Deutsche Bundesbahn.

GREECE.

33) Greek State Railways.
34) Pireus-Athens-Peloponese Railways.
35) Thessaly Railway.

HOLLAND.

36) Netherlands Railways.

HUNGARY.

37) Hungarian State Railways.

ITALY.

38) Ferrovie dello Stato.
39) Tranvie Elettriche di Brescia.
40) Ferrovie del Mediterraneo.
41) Società Nazionale Ferrovie e Tranvie.
42) Ferrovia Nord Milano.
43) Ferrovie Secondarie della Sardegna.
44) S. A. Italiana per le Ferrovie del Sud-Est.
45) S. A. Torinese Tranvie Intercomunali.
46) Società Veneta per la Costruzione e l'Esercizio delle Ferrovie Secondarie in Italia.
47) Azienda Tranviaria Municipale di Milano.
48) Compagnia delle Ferrovie Danubio-Sava-Adriatico.

JUGOSLAVIA.

49) Chemins de fer de la République Populaire Fédérative de Yougoslavie.

LUXEMBURG.

50) Société Nationale des Chemins de fer Luxembourgeois.

POLAND.

51) State Railways.

PORTUGAL AND COLONIES.

52) Portuguese Railways Company.
53) State Railways.
54) Benguela Railways.

RUMANIA.

55) Rumanian Railways.

SPAIN.

56) R.E.N.F.E. Red Nacional de los Ferrocarriles Españoles.
57) Compagnie Générale des Chemins de fer Catalans.

SWITZERLAND.

58) Schweizerische Bundesbahnen (S.B.B.).
59) Bern-Loetschberg-Simplon Bahn (B.L.S.).
60) Rhaetische Bahn.
61) Visp-Zermatt Bahn.
62) Chemin de fer d'Yverdon à Sainte-Croix.
63) Chemin de fer Fribourgeois.
64) Emmental-Burgdorf-Thun Bahn.

SYRIA.

65) Syrian State Railways (Northern Line).
66) Chemin de fer de Damas, Hama et prolongements.

TURKEY.

67) Turkish State Railways and Harbours.

2. — In all 37 replies have been received: of these 23 have advised that they are not in a position to give any answer to the questions in the questionnaire, either because of the limited size of electric traction or for the particular nature of the services operated, or even for the non-existence of this system of traction on the respective railway systems. Only 14 Administrations have given replies which are of any use to this report.

We are glad to thank most heartily all the Railway Administrations for their courteous collaboration which has enabled us to plan our work.

With a view to giving a better framework to our report, we give in Appendix No. 1 a synoptic picture shewing the Administrations which have replied positively, and the complete développement of the railway systems under examination subdivided according to the various systems of traction in use.

3. — *General remarks on the replies received from some countries and networks.*

We must now make a few general remarks on some of the replies received.

The « Société Nationale des Chemins de fer Vicinaux belges » have a network of suburban and inter-urban lines on which principally a passenger service with the typical characteristics of suburban traffic, and a very small freight traffic is run. It did not appear that the comparison between the details supplied by this Company and the others can be of any use in view of the fact that all those dealing with a similar traffic have supplied no information.

The Bas-Congo - Katanga Railway Company operates only one line Jadotville-Tenke opened in October 1952 and has the extension Tenke-Kolwezi under construction. This line will have a negligible passenger traffic while freight traffic expectations are high; however, the details supplied in the replies are estimated as, at present, no définite statistics are available.

The « Société Nationale des Chemins de fer Français », in view of the great extension of the network and great differences in operation and traffic conditions existing within the network itself, have supplied details relative to three examples only, as follows :

Paris-Le Mans;
Paris-Lyon, and
Valenciennes-Thionville.

These lines have been specially selected to represent sectors of identical traffic and sufficiently independent of the remainder of the network to enable the S.N.C.F. to supply separate details.

In addition these constitute sample lines for the different systems of electrification in use in France. In fact, whilst the Paris-Le Mans line was opened before the war with 1 500 V, D.C., the Paris-Lyon line, although electrified with the same system, represents the most modern of this type that there is in France.

Finally, the Valenciennes-Thionville line not yet electrified will be the first large French application of the single-phase standard frequency current system : it is expected that this line can be opened for operation in 1954. Therefore, the details referring to it are the results of accurate estimates made by the S.N.C.F.

The management of the Algerian Railways has prepared a very interesting report on their network especially as far as the problem of the feed of the network is concerned; however, it has not always been possible to extract details from the report which can easily be compared with all those supplied by the other Administrations.

The Spanish State Railways, in its valuable report, has supplied statistics as far as the existing network is concerned and has further replied with estimated details relative to the network in course of electrification, for which a sample line, the Leon-Ponferrada, has been selected for its special characteristics.

A general observation should now be made in connection with the fact that for obvious reasons of different organisation of the individual administrations not all the replies are equally complete or faithful to the questions asked.

Therefore, our task has not been easy as it has appeared necessary, even by elaborating the details, to obtain results which would not lose their validity in connection with the theme which is essentially that of comparing the various systems.

For example, a comparison between different systems in the field of metropolitan or suburban traffic would have been very interesting, but unfortunately we have only one reply in this connection, which fact has made it impossible for us to dwell on this subject and has compelled us to limit the field of action to the main railway systems only especially in view of the fact that no reply regarding metropolitan railways has been received (*).

4. — *Countries and networks to which this report refers.*

Therefore, for the considerations stated above, and for the purposes of our report, this study is limited to the following Railway Administrations :

1. ALGERIA — Algerian Railways;
2. BELGIUM — Belgian National Railways (S.N.C.B.);
3. CONGO — The Bas-Congo - Katanga Railway Company (C.F.B.C.K.);
4. FRANCE — French National Railways (S.N.C.F.);
5. GERMANY (Western) — German Federal Railways (D.B.);
6. HOLLAND — Dutch Railways (N.V.N.S.);
7. HUNGARY — Hungarian State Railways;
8. ITALY — Italian State Railways (F.S.);
9. MOROCCO — Morocco Railway Company;
10. SPAIN — Spanish National Railways (R.E.N.F.E.);
11. SWITZERLAND — Swiss Federal Railways (S.B.B.);
12. SWITZERLAND — Bernese Alps Railway (B.L.S.).

Some of the more important replies given to the questionnaire by the above mentioned Administrations have been collated in the attached tables, details for the S.N.C.F. and R.E.N.F.E. relative to the sample lines being kept separate.

5. — *Currency and rates of exchange.*

With the object of making all the details of an economic nature uniform, the relative figures have been quoted in Swiss francs, taking the following list of rates of exchange as the basis according to quotations at the Milan Exchange on 22nd July, 1953.

100 French francs = 1.085 Swiss francs
100 Belgian francs = 8.250 » »
100 Western German Marks = 99.150 » »
100 Dutch Guilders = 109.000 » »
100 Pesetas = 10.200 » »
100 Italian Lire = 0.685 » »
100 Pounds Sterling = 1 000.990 » »

CHAPTER II.

GENERAL OBSERVATIONS.

1. — *The theme of the present London Congress and the Cairo Congress of 1933.*

After 20 years the Congress returns to concern itself with electric traction. Then — as now — it was the economic aspect of electrification which was being dealt with; characterized by the position of the sources of energy and by the choice of system. Therefore, then — as now — these basic aspects of the problem were placed remarkably in evidence in the title of the theme proposed to the Congress.

No-one, therefore, will be surprised if today's Reporter, not only again takes the fundamental motives of the very valuable reports presented at Cairo in 1933, but, in addition, attempts to write his own, as far as possible, in order to continue these and to complete them with all that the evolution of time and technical experience has taught.

But, even in their apparent similarity, the themes of the two Congresses, of Cairo and London, shew a notable difference. At that time, the economic problem of electrification was directed towards investigating the convenience of electrifying, and — as such — was based on the economic comparison between electric traction and « the other », that is, at that time, steam traction. Today, instead, the Congress requests an economic examination within electric traction itself, that is between the different systems of electric traction technically and practically possible.

(*) The reply from the « Régie Autonome des Transports Parisiens » has arrived only when this report was already finished.

The fact of having circumscribed the examination of the problem must certainly not be interpreted in the sense that the more general aspect of comparison between electric traction and « the other » is no longer of interest. If anything, the contrary has occurred, seeing that today diesel traction has established itself alongside steam. We must instead interpret the theme proposed to us as a desire to give a view, complete if possible, of the choice of the system as it presents itself today when — at the beginning of the second half of our century — electric traction in its great railway application, has completed 50 years of experience.

2. — *Short historical note : The present systems and those examined in this report.*

This is not the place to quote in detail the development of the different systems of electric traction. It will be sufficient simply to mention a few salient facts which, besides notable historical importance, have, even if indirectly, a present day importance. They can be summarised as follows :

a) Electric traction was first started with direct current and moving around voltages of 100 volts, soon reached 500 volts. It began and developed itself in the same period with the use of individual axle drive, prevalently with gear transmission : the applications in this period were of the tram type.

b) The passage from the low power used for trams to the more important railway applications called for an increase in the voltage of the overhead supply system and the abandonment of individual axle drive and gear transmissions.

The three-phase system was the first to solve in this way the question of railway electrification, followed in a very short space of time by single-phase, almost immediately using low frequency.

c) The direct current system then also passed the 500 volt limit, and passing through several difficulties, reached 1 500 volts.

d) There was then a period during which three systems of electric traction were competing with each other : three-phase, single-phase (both at low frequency) and direct current at 1 500 volts.

The first gloried in the benefit of simplicity of construction of the locomotives and in the possibility of regenerative braking, but was blamed for the severe constructional complications relative to the electric feeder and overhead supply systems and for the very limited possibilities of speed regulation in the locomotives.

The second, with no lesser complications as far as the supply to the substations is concerned, and with complex locomotives with a low specific power boasted of wide and easy regulation, of great simplicity in the construction of the overhead supply system and of the notable distance between the substations.

The third, even if not permitting such light overhead supply systems as the single-phase and requiring substations fairly close together, had the advantage of simplicity of feed, of strength and simplicity of traction motors and of locomotives which shewed themselves to be of satisfactory specific power.

e) The above-mentioned co-existent systems were perfected, attempting to make up for their deficiencies.

The three-phase system, by not always simple artifices, managed to attain 4 economical characteristics, which, however, could give only 4 constant speeds; the single-phase gradually increased its specific power; the direct current system tried the use of voltages up to 3 000 volts with rotary converter substations (*). Meanwhile the constructional perfection of the gearing enabled single-phase and direct current to prove the

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(*) Voltages were also attempted till 4 000 volts (f.i. the Valli di Lauzo Railway in Italy), but the occurring difficulties compelled to fall back on the values nearer to 3 000 volts (f.i. in Italy 3 400 volts in the F.S. [State Railways], and 3 600 volts in the above mentioned Valli di Lauzo Railway).

benefits of individual axle drive and, at the same time, enabled the three-phase system to make a satisfactory experiment in the use of currents at standard frequency for the feed to the overhead lines, thus simplifying to a marked degree the feed to the electrified railways. At this point, the perfection of mercury-arc rectifiers and of track-feeder circuit breakers for high voltage D.C. definitely opened the field to electrifications with direct current at 3 000 volts.

f) When, in 1933, the previous Congress was occupied with electric traction the situation then was precisely that the choice of system for the great railway electrifications concerned, in practice, those of direct current at 1 500 and 3 000 volts and single-phase at 16.66 cycles, in view of the fact that three-phase had been considered as superseded even in the country of its origin.

g) At the present time — apart from the existence in N. W. Italy of a small three-phase, 16.66-cycle railway system (destined to be converted to direct current at 3 000 volts) and apart from lines of a local or metropolitan character with direct current at voltages of 500 - 1 500 volts, the systems used are those referred to in *f*), to which has recently been added the standard frequency single-phase system. The latter has had an important application in Hungary, whilst those in Germany (Höllental) and France (Savoie) are rather of an experimental nature. The last of these (even though small quantitatively both in extent and size and intensity of traffic), for the amplitude of studies made and variety of solutions adopted, presents a quite outstanding interest.

From the results obtained, France and Belgium have taken the opportunity of electryfying respectively the Valenciennes-Thionville line (quantitatively the most important in chronological order after the Hungarian) and the Bas-Congo - Katanga Railway.

The advantages awaited from the development of the last system are well-known, and here in this report there will be the opportunity of examining them. It is also known that it lends itself to the use of locomotives which carry out on board notable changes in the nature of the current, in such a manner that some distinguish between single-phase/D.C. system or single-phase/three-phase system and the single-phase commutator type motor. But if — without considering what happens in the locomotives — reference is instead made to the nature of the current used to supply the overhead supply system, it can be said that — for the great electrifications being dealt with — there exist two systems : that of direct current and that of single-phase alternating current. Each of these, then is obtainable in two ways, different for direct current by reason of the different nominal voltage in the overhead supply system (1 500 and 3 000 volts) and for alternating current because of the different frequencies (low and standard, which on the networks referred to in this report are respectively 16.66 and 50 cycles).

One cannot, however, do otherwise than to illustrate at this point how « the question of the system » presents itself in a manner far different from that in which it did 20 years ago, above all because the high technical qualities of the systems already in existence have favoured their development to such a degree that in many countries it would be very difficult for a new choice to be put on a sound basis.

CHAPTER III.

TECHNICAL EXAMINATION OF THE FUNDAMENTAL CHARACTERISTICS OF THE SYSTEMS OF ELECTRIC TRACTION.

It is advisable, first of all, to give a comparative examination of the technical characteristics of the two systems of electric traction quoted.

A. — The supply of power.

1. — *The question of power stations and high voltage distribution lines for the exclusive use of railway electrification.*

From the point of view of supply to the overhead supply system, the following three cases can be considered :

1) direct current;

2) single-phase low frequency alternating current;

3) single-phase, standard frequency alternating current.

In the first and second cases the overhead supply system cannot be fed from the three-phase alternating current public supply system except by the insertion respectively of a converter from three-phase alternating current to direct current or to single-phase, low frequency alternating current.

For electrification with direct current, the only solution is to install converters (or rectifiers) in each of the substations feeding the overhead supply system.

On the contrary, for electrification with low-frequency alternating current, three solutions are technically possible :

a) by having phase and frequency rotary converters in each substation;

b) by concentrating such converters in a few stations connecting the public supply system to a special low-frequency power line to be used exclusively for feeding the substations which would then only be required to carry out the simple operation of changing the voltage; and finally

c) by generating single-phase current at low-frequency for the exclusive use of the railway and distribute it by means of a special low-frequency single-phase power line as mentioned in point *b*).

As far as the railways electrified by means of standard frequency single-phase current are concerned, the possibility of connecting the substations to the nearest point in the public supply system appears obvious, these substations having the sole function of changing the voltage.

As shewn in Appendix No. 3, the main lines in Germany (D.B.) and Switzerland (S.B.B.) electrified with single-phase, low-frequency current are the owners, wholly or partly, of the power stations generating electricity for the railways. The other systems in general do not require such ownership : the only important exception is Italy whose main railway system (F.S.) owns power stations for both three-phase low-frequency (for reasons already illustrated for single-phase of the same frequency) and for 3 000 volt direct current.

From what has been said up to now, it appears that — with the exception of the two solutions already quoted for electrification by means of single-phase low-frequency current requiring special high voltage distribution lines — in all other cases of electrification either with single-phase alternating current or with direct current, it would not necessitate the construction of either special power stations or high voltage distribution lines with the specific function of supplying power to the railway.

This, at first sight, would appear to be in contrast to the fact that some railway systems electrified with direct current are equipped with high-voltage distribution lines constructed specially for their supply. Twenty years ago, in Cairo, the reporters JAPIOT and LEBOUCHER recognised the direct current system as being the most advantageous for the very reason that it gave rise to the construction of inter-connecting high-voltage lines between centres producing electricity for public use.

In actual fact, direct current electrification does not, in principle, require high-voltage distribution lines in that the converter substation can be connected to the nearest point of the public supply system. Where, however, the regularity in the supply of electric power would not have been sufficient for railway purposes, or where even, pick-up points of sufficient power did not exist, it has been necessary to construct high-voltage distribution lines to provide power or to inter-connect various sources of power; it is, therefore, evident that the reasons for this construction are quite independent of the system of direct current selected for traction and that they would also be necessary with any other system of traction.

The benefits derived from inter-connecting high voltage lines have been generally much greater than would appear from the sole point of regularity assured to the railway service. These, through the security of supply of electric power, have been abundantly showered on all the other industries in the inter-connected regions. It is for this reason that the reporters of twenty years ago attributed such importance to direct current electrification, the only type which at that time permitted the realisation — for railway needs — of satisfying the necessity felt for the regular supply of electric power over vast areas.

The high voltage three-phase lines constructed for the railways electrified with direct current are not only not for exclusive railway use, but, in fact, convey considerable quantities of power of which the proportion destined to railway use often represents a small part. As shewn, in fact, in Appendix No. 4, of the countries and railway systems to which this report refers, those which adopt the single-phase low frequency system are the only ones in which, without exception, the substation feeder power lines are almost entirely the property of the railway, and do not convey power for other uses, apart from exceptional or particular cases.

For the other systems these high voltage lines are either branch lines for the connection of the substations to the nearest point in the public supply system or are the property of the suppliers of power (in which case exclusive allocation to railway use constitutes an exception), or else are railway property but also convey power for other users. From this point of view the case of Italy is outstanding, where the F.S. are the owners of a great high voltage three-phase network of which the primary function of inter-connection is evident. If one considers the ownership by the F.S. of several important standard frequency power stations, one would be correct in believing that the investments of the F.S. for the considerable entity of the production and distribution of electric power at standard frequency were required for reasons not dependent upon the chosen system of traction : in fact, it must be added that the ends which such installations were intended to achieve would not have been reached with the single-phase low-frequency system, the only alternative of choice (except, of course, three-phase) existing at the time when Italy decided upon the programme of direct current electrification.

Italian experience shows then that the power line network of the railway meets more requirements of national interest, in the carrying of electric power from one end of the long peninsula to the other and in the connection of very different hydrological basins, than the mere railway supply.

At the present position of regularity required in the public supply of electric power and of compensation between production centres geographically distant and having complementary production diagrams, one must exclude the fact that the onus relative to the great standard frequency three-phase high voltage distribution lines should be considered as a technical necessity of electrification, even if contingencies sometimes require their construction at the time of railway electrification.

In particular, it appears that it can be stated that many large electrifications carried out with the direct current system have been accompanied by the growth of a high-voltage system of inter-connecting lines for historical reasons only, inasmuch as at the time when the reason arose for such a system, the direct current system was the only one permitting the use of one high-voltage line for both the railway supply and for inter-connection. In all the other cases in which, independently of this requirement, it was necessary to construct a high-voltage line system for railways electrified with direct current, it would also have been necessary with any other system of electric traction.

It appears, therefore, that one can affirm that, in principle, all systems of electrification — with the one exception of low-frequency single-phase, in the case of substations with the one function of voltage transformers — do not require, for their nature, the construction of a special high-voltage line system.

In any case, whatever type of current may be adopted for the supply to the overhead supply system and however such supply may be realised — no difference, from a technical point of view, exists between the various systems insofar as the results and operational possibilities are concerned. It is always possible, in fact, to obtain the supply to the railway with a regularity sufficient in any case, for all railway requirements.

2. — *Substations.*

Passing now to consider the substations feeding the overhead contact line, it is known that the two types of current involve differences in the type of machinery employed in them.

These can be subdivided into rotary and static, among the former being listed the rotary converters of alternating current to direct (both with co-axial and with single armature machines) together with rotary converters of phase and frequency; instead among the latter are included the voltage transformers and the static rectifiers of alternating current to direct current.

The rotary types — all this is well-known — are more delicate in operation and therefore less reassuring (this fact is confirmed, for example, by the report of the Algerian Railways in this connection); with the direct current types, the restriction of the maximum voltage between the lamellae of the commutator still continues and involves the use of two generators connected in series for voltages in the overhead supply system above 1 500 volts. Among the static types, the transformers are the simplest as their operation requires very little supervision which can very easily be made automatic. The mercury-arc rectifiers, which proved to be very successful in contrast with the rotary converters in direct current electrifications, have — for about ten years — been undergoing improvements intended to relieve them of the numerous difficulties in connection with their auxiliary services especially as far as cooling and vacuum are concerned. Noticeable progress has been made especially in connection with cooling. Many substations are, in fact, equipped with rectifiers of great power (2 000 kW and above) cooled by forced draught. The use of the six anode type is being extended. Progress in connection with the vacuum has not been so noticeable. While, in fact, tram and light-railway substations have often been able to install rectifiers without vacuum pumps, so far this has not been possible on any of the railway systems to which this report refers (*). A very interesting improvement of the mercury-arc rectifier is that of the utilization of grid control, not only for the purpose of better operation as a rectifier and as a good protection against back-fires (which compromise the life of the transformers) but also to permit their employment as converters and particularly to obtain phase and frequency converters. Thus it is possible to feed the overhead supply system with single-phase electric power from high-voltage three-phase distribution lines. From technical literature it is well-known that the German Railways experimented with an installation of this type in the Basle substation but no further application has been made. In the replies to the questionnaire no information is included about this very interesting prospect or of the reasons which have discouraged its further employment. What is known is that the control and, above all, the protection from back-fires, is one of the most delicate aspects of their operation.

The differences existing between the dif-

(*) Just now the F.S. have installed in Verona substation 2 mercury arc rectifiers without pumps of 1 000 kWh.

ferent types of equipment bring with them as many differences, often important ones, in the constructional and operational technique of the substations; but, in general, it can be said that, apart from each one's own characteristics, all of them prove to be able to satisfy all the requirements of railway electric traction.

From the constructional point of view, it must be pointed out that the delicacy of the rotary converters and of the rectifiers does not, in general, permit their installation on open sites, which is, instead, widely possible with transformers. For this reason, the constructional complexity of the substations is greater — normally — in those with rotary converters and is reduced to the minimum in those with transformers only, whilst those with mercury-arc rectifiers remain in an intermediate position. It should, however, be remembered that in this sector of electrification technique, the years have not passed in vain and constructors have from time to time adopted solutions intended to further simplify installation complexities, so that it is not surprising that, for example, certain modern substations with rectifiers are already very simple and definitely not much more complex than those with transformers only, with consequent beneficial consequences as far as the importance of the necessary buildings are concerned. This means that each comparison must be based not only on what has already been done in the past years, and thus in a different technical stage and degree of progress, but also, above all, having in mind what it is possible to do today.

As far as operation is concerned, it is to be remembered that the complexity of controls and maintenance increases with the operational delicacy of the equipment; this, therefore, is greatest with the rotary types, least with the transformers and intermediate with mercury-arc rectifiers. It follows that the difficulties in using the rotary machinery in unstaffed substations are greater : among the railway systems to which this report refers, the only case of its use in automatic substations, is that of the Morocco Railways.

3. — *Electric braking and the question of the reversibility of the direction of energy in the substations.*

It is well-known that the advantages of the use of electric braking — according to widespread opinion — lie not so much in the possibility of realising regeneration and economy of power, as in the possibility of avoiding the high cost arising out of consumption of the brake shoes, and — in some cases — in the possibility of having an inexhaustible brake available — very useful on long down gradients. It is also known that, in the two systems of traction under examination, such electric braking can be effected by the tractive units either by discharging the energy generated into a rheostat on board or by returning it to the overhead contact line. It is for the latter cases that the name « regenerative braking » is generally reserved. In the former case the question of electric braking exhausts itself within the limits of the tractive unit, whilst in the second it also affects the fixed installations and the feed of the overhead supply system.

In the case in which normal use is made of regenerative braking, it must further be distinguished if the energy supplied to the overhead contact system by braking tractive units can be used by others at that moment in traction (*); or instead, if there are no others, whether a change in the direction of power takes place in the overhead supply system and its connections to the substations; which can only take place if the equipment installed in these substations permits it.

Let us observe, first of all, that, of the railway systems to which this report refers, some have no interest in this; others, instead, do. Among the former are included the S.N.C.B., F.S., Holland, France and Germany; among the latter, Algeria, Mo-

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(*) As it may easier happen for both the tramway- and urban and suburban railway-networks.

rocco, R.E.N.F.E. and S.B.B. (to a limited degree). As is seen, interest in the question does not depend upon the chosen system of traction but — as at least one gathers — upon the nature of the traffic and the lines.

Well, now, all the types of substation equipment of which we have spoken can be fairly easily utilised for the flow of power in a reverse direction (the transformers without any particular arrangement), with the exception of the mercury-arc rectifiers. We thus see (see Appendices Nos. 16 and 17) that on those lines electrified with direct current on which regenerative braking is employed, rotary converters are adopted for this purpose instead of mercury-arc rectifiers, in spite of the greater complexity which this choice involves.

In Algeria and Morocco mercury-arc rectifiers or rotary converters are used in the substations on the same railway line according to whether or not the substations will be affected by the inversion in the flow of power. One substation only, that of La Grandja on the Spanish Leon-Ponferrada line, in course of electrification with 3 000 volts, D.C., is to make use of an inverter rectifier; instead, in Algeria, in the Tebessa substation, equipped with mercury-arc rectifiers, it has been considered convenient to install a rheostat for the absorption of the energy coming from regenerating trains; a solution which, as far as the automatic control of inserting the rheostat is concerned, does not appear to be any simpler than that required for the inverter rectifier.

One must recognize that at the present state of things in the countries and on the railway systems to which this report refers, a sufficient experience of, or confidence in inverter rectifiers does not exist; which fact, obviously, would put electrification with direct current, especially at 3 000 volts, in a difficult technical position if this requirement was considered indispensable.

4. — *Unbalancing effects on the three-phase systems of single-phase loads.*

And now — still on the subject of substations — we are faced with another delicate problem : the feed of the single-phase overhead supply system from a three-phase high-voltage line of the same frequency for which normally two single-phase transformers, connected according to the known scheme of SCOTT, are used. The unbalance of the loads withdrawn in the two single-phase lines generates a corresponding unbalance in the three-phase high-voltage supply line, with the well-known consequences.

On the other hand, practical operation of the three-phase high-voltage distribution lines shews equally well that, within certain limits, this unbalance can be easily sustained; limits which depend upon the relation between the power available in the distribution system and that withdrawn in an unbalanced manner at the points destined to supply the railway substations and also on the spacing of these points and the extent to which it would be possible to distribute the railway load among the three phases of the main system.

However, this question of unbalance created in a three-phase line by single-phase loads has recently been the subject of an animated discussion among electric traction technicians. This discussion is justified by the fact that as yet we are lacking a concrete and sufficiently wide experience in connection with this problem of electric traction. The only widespread application made up to now is that of the Hungarian Railways for the feeding at standard frequency of a single-phase overhead supply system, whilst the German application on the Höllental and the French on the Upper Savoy are, to tell the truth, not considered to be sufficiently indicative in view of the modest size of the railway electrification. In the Höllental, however, the results were not satisfactory because unbalance was found of 3 % at the generators, 6 % at the point of connection to the main system and 12 % at the Titisee substation.

On the other hand, the Hungarian Railways have not replied to any point of parag. 7 of Chap. B of the questionnaire (the reply says textually « il n'y a pas »); the S.N.C.F. advise that in connection with the future 50-cycle single-phase electrification of the Valenciennes-Thionville line they will have the same obligations towards the suppliers as they already have for the 1 500 V direct current railway systems; but the price of power is a little higher (0.06 Sw. fr. per kWh) for this line than for the Paris-Le Mans line (0.058 Sw. fr. per kWh) and the Paris-Lyon line (0.057 Sw. fr. per kWh). Finally, the Bas-Congo Railway advised that they are not supposed to exceed a 2.5 % unbalance.

At the present state of experience of electric traction in this respect, any pessimistic or optimistic judgement is premature. We should have much better possibilities of judgement if the French electrification of the Valenciennes - Thionville line were already carried out, or if Hungary had supplied more precise details. Obviously the question is of particular interest in connection with electrification with standard frequency single-phase currents, in regard to which it might therefore be said that they can be fed from the nearest public supply system as long as the latter has sufficient power as compared with that picked-up for railway purposes.

Does this condition place technical limits on the application of the single-phase system with currents of standard frequency? It is not easy to reply to such a query, particularly with the present lack of sufficient practical knowledge; it is not inviting to prophesy with the risk that some future Reporter re-examines this report and finds it to be wrong. Anyway, it will be convenient for the purpose of orientation to specify some ideas.

Even though the standard frequency single-phase system — compared with the low-frequency and direct current system — can, to a certain extent, lower the limit of traffic below which electrification is no longer convenient, this limit will always be such as to place the railway for which it is studied among those of intense traffic as compared with the others which it is not intended to electrify. This means to say that the power necessary for electrification, even though small, will in general be sufficiently large; so that the power in the public supply system must be much higher. Such electrifications, therefore, would appear to be convenient in industrially developed areas where there already exists a wide consumption of electric power.

Instead, caution would be required in the electrification of a railway with standard frequency single-phase current in a zone where such wide consumption did not exist; unless the power installed by the railway could be conveniently reduced (in which case this would be a railway with limited traffic and its electrification only suggested by considerations of a technical order).

On the other hand, it must not be forgotten that (as recognised by M. S. WITHINGTON in his report at the Cairo Congress) these conditions, regarding the relation between the power required by railway electrification and that in the public supply system to which it is connected, are not only required by the problem of unbalanced loads but also by that of voltage regulation, in that the considerable variations dependent upon the heavy oscillations of the railway load would be badly sustained by the public supply system.

In actual fact, that is, the requirements connected with the question of unbalance would be satisfied at the same time as the others connected with the feed of an electric railway with no major practical complication.

All this, of course, on the assumption that the single-phase loads in the overhead supply system are unbalanced.

It is not to be excluded, however, that such unbalance can, in determined circumstances, be considerably reduced, as may happen, for example, where frequent light trains, almost uniformly distributed over the sections between the substations are running on the railway; one could then think of feeding the railway from a three-phase high-voltage line even when the ratio between the two, frequently quoted, powers are not more favourable. Unfortunately, however, this is also an aspect of the question of which there is insufficient knowledge to permit a safe opinion.

Enthusiasts of the 50-cycle single-phase system seem to be sure of practically unlimited possibilities; technicians must be grateful to them, both because this enthusiasm helps progress and also because the practical results they achieve constitute a concrete basis to obtain with perfect knowledge documentary opinions on the subject. The jealous defenders of existing consolidated techniques are not absent — techniques which, however, for many reasons it seems cannot be pushed aside by the new.

On this subject, therefore, waiting is justified, as much suggested prudence is hastened by the hope of success.

5. — *Nominal voltage in the overhead supply system.*

Nearly all the problems of electrification are dominated by the choice of the voltage in the overhead supply system. Its repercussions on the most essential technical and economic characteristics of the systems are not only important, but of many forms, so that only with difficulty can a complete and efficient synthesis be made. The interest surrounding such a choice does not become diminished by considering that, in practice, habit and the consequent industrial unification of many materials, have restricted it. In this report one cannot refrain from mentioning the importance of the problem as a question of principle, as the possibilities of choice, even if limited, still exist with their full consequences both for direct current — which in addition to the lower voltages of 500 - 800 volts, of 1 000 - 1 200 volts adopted in minor electrifications, makes use of 1 500 and 3 000 volts for the more important ones — and for the new standard frequency single-phase system for which the choice moves in a completely fresh field.

We shall not repeat here the well-known considerations regarding the technical and economic advantages and disadvantages which — on a theoretical level — accompany the adoption of high voltages. We consider it instead more useful to put ourselves on the practical level of the problem as it presents itself after 50 years' experience of electric traction.

Let us note first of all, that no matter what the value of the nominal voltage in the conductor may be, the choice of the maximum admissible drop is regulated for both systems by the same principles and leads to practically the same figure in relative value. In view of the fact that the drop in voltage for both systems is connected with the loss of energy in the overhead supply system and has the effect of reducing the speed of the traction motors without altering their torque (here we consider only the employment of commutator traction motors directly supplied from the overhead supply system) the acceptance of more or less high drops in voltage depends upon within what limits it is desired to maintain the loss, and the quality of railway service required.

As far as the first are concerned, the problem of the drops can be laid out in economic terms making a comparison of the total cost as a function of the drops themselves. This research, however, may be saved in the majority of cases because the cost of energy represents a relatively small part of the total, so that economy in the consumption of power has not, in general, very important effects; on the contrary investments made in the immobilisation necessary to reduce the drops in voltage constitute worrying financial sacrifices. The result is a tendency to raise the maximum amount of drops to the point at which it is compatible with the quality of railway service that is required.

In practice, in connection with both the D.C. and single-phase systems, regardless of the nominal value of the voltage, the maximum permissible drop, according to the various railway lines, varies from 1/5 (on rare occasions 1/5.5) to 1/3 (on rare occasions 1/2.5) of the nominal value as shewn in Appendix No. 7.

Definitely, therefore, the increasing of the nominal value of the line voltage increases the absolute value of the drops and with the same power decreases the current; which fact permits the overhead supply system to be lightened and the spacing out of the substations.

As far as lightening the former is concerned, it should be observed that this cannot be carried beyond limits imposed by the strength which the line itself must have to satisfy requirements of a mechanical nature concerning its stability in face of changing atmospheric conditions and also by the regularity of the collection of current by the locomotives and the stability of their pantographs. There are, in practice, minimum dimensions of the overhead supply system below which it is neither convenient nor advisable to go, so that any further increase in the voltage would have the effect of only spacing out the substations.

At the present state of technical knowledge and experience of the railway systems to which this report refers, it appears that these minimum dimensions of the overhead supply system on important railway lines with fast trains are those adopted by the railways electrified with the single-phase low-frequency system which normally use a copper contact wire of approximately 100 sq. mm suspended over the track from a catenary wire which can equally be of copper with a similar section of 100 sq. mm; or in steel or bronze with approximately half this section.

The considerations made up to now apply, generally speaking, to both the systems with which we are concerned; but the benefits derived from the increase in voltage do not themselves increase to an equal degree with both systems, because of the drop dependent upon reaction in the single-phase system, which depends very little upon the electrical and geometrical characteristics of the overhead supply system but instead increase noticeably with the decrease of the power factor and with the increase of the frequency of the current. This power factor, where single-phase locomotives with single-phase commutator traction motors are concerned — in the most severe conditions under which the drops in voltage occur, that is, in starting, is very low. It therefore follows that, with equality of nominal line voltage, of dimensions and strength of the overhead supply system, of percentage drop in voltage and of nature of traffic — the spacing of substations is greater with the direct current system than with single-phase, from which it follows that low frequency is more convenient that standard frequency.

Another element which has a considerable influence on this complicated problem is the technical possibility of establishing the parallel between the substations through the overhead supply system which reduces the drop in voltage to an important degree. It this connection it should be observed that, whilst this parallel is always possible with direct current, it is possible with single-phase current only when the substations themselves carry out the frequency conversion (where necessary) or where the latter, being only voltage transformers, are supplied from the same source of energy.

This latter condition occurs in practice where there is a special high-voltage line or an inter-connecting high-voltage network which, directly or indirectly, feeds all of them at the same time from one power station or from groups of power stations in parallel.

This eventuality (which is of great importance for electrification carried out without the construction of special high-voltage lines for railway use) cannot always be found in practice, especially in large areas. In other words, the single-phase standard frequency system must foresee the impossibility of being able to always establish the parallel between two successive substations. This does not mean, be it clearly understood, that such an unfavourable circumstance must necessarily be anticipated for all the substations and for the whole time of the operation of the service. It is, in fact, evident that, in relation to the practical circumstances in which the feed is carried out, it will be possible to find out which substations have a common feed and which do not, and for the latter, how long this situation may be expected to last. But it is equally clear that all this involves the acceptance of possible higher drops in voltage or the giving up of the full exploitation of some technical possibilities, or constructional and operational complications.

Definitively, therefore, making specific reference to the practical aspect of the question, supposing that every perfection intended to lighten the overhead supply system has been pushed to the utmost without detriment to its strength, and supposing that the maximum drop in voltage compatible with the quality of service has been fixed, to obtain a desired spacing of the substations, still higher nominal voltage in the overhead supply system will be necessary passing from direct current to single-phase low-frequency and standard frequency currents.

Notwithstanding, however, the evident advantage which, in principle, direct current offers, unfortunately it is not possible to utilise and manipulate easily continuous voltages of over 3 000 - 3 400 volts. In fact, whilst the mercury-arc rectifiers could permit the attainment of a voltage of 6 000 V and whilst no particular difficulty would arise in connection with the overhead supply system, on the contrary, very great difficulties would be met in connection with the track feeder circuit-breakers and the rolling stock, for which it would be necessary to have many motors permanently connected in series. This fact would oblige locomotives to employ more complex wheel-arrangements or to drive each axle with several motors, and oblige electric motor coaches to be operated with several permanently coupled.

No limit exists on the contrary, in principle, for the single-phase system, for which the choice of voltage may be led back to the general technical and economical principles followed in the ordinary distribution of electric power. This has brought the adoption of voltages of 10 000 - 25 000 volts to the realms of technical possibility. But the fact remains that whilst using much higher voltages in electrification with single-phase current than those used with direct current, the spacing of substations — all other conditions being equal — does not increase in proportion. We can, therefore, note that with a voltage of 3 400 volts, direct current, there is a corresponding spacing of substations of about 40 km, whilst with the 15 000 volt single-phase low-frequency system the average corresponding distance is barely double, to maintain which with standard frequency it is necessary to raise the voltage to 20 000 - 25 000 volts. This has no technical consequences as far as the construction or operation of the substations is concerned, but has some affecting the overhead supply system, of which we shall speak.

B. — The overhead supply system and the contacts.

The conductor rail system has been excluded from the theme fixed for the Congress. The use of this, in fact, for well-known reasons, is limited to lines which are electrified at low voltage and which are not readily accessible to persons other than railway staff : the case of the 1 500 V D.C. lines in South Eastern France is an exception which — as the S.N.C.F. itself says — is not to be extended.

6. — *Collection and pantograph stability.*

The exigencies relative to the collection of current by means of fast moving contacts, sliding under an overhead conductor are well-known. They concern, on the one hand, the adequate proportioning of the surface of the sliding contact and of its pressure against the contact wires, in order that it is possible to collect the current required for the power of the locomotive, and on the other hand, the planning of the pantograph collectors and the overhead supply system in such a way that abnormal movements and vibrations to which both these parts are subjected by the fast movement of the locomotive do not cause break of contact — and thus interruptions in the feed of the traction circuit — or worse, shocks or entanglements with resultant damage to these parts.

As far as the above-mentioned proportioning is concerned, the surface and pressure in question must be as correspondingly high as is the current to be collected thus with the increase of the latter the pantograph collector becomes more complicated and often less suitable from the point of view of stability of collection itself. Thus those systems find themselves in an advantageous position which require the collection of lower currents, which, with equal power of the locomotives, occurs with the use of the highest possible voltages in the overhead supply system. With electric traction with alternating current the power factor, following a proper law of variation with the speed and with the load, assumes very low values in starting, which fact reduces somewhat the advantage of the higher possible voltages which the single-phase system has over the direct current system.

As far as the stability of the pantograph is concerned, apart from what has already been said of the influence which the intensity of current to be picked up has, it can be said that no difference exists, generally speaking, between the different systems, as far as their planning is concerned. On the contrary, for the overhead supply system it must be noted that, if in order to restrict the drop in voltage within the limits desired it must have a considerable wire section, certain constructional or mounting complications may be necessary in order that the size of the section does not give rise to a too rigid system : it is thus still the direct current system — especially with the lower voltages — which finds itself in the worse condition.

However, with any system, universal use is now made of overhead supply systems suspended longitudinally with one or more catenary wires. According to the cases, as is known, different types of overhead supply systems are adopted, simple or multiple, inclined or upright, rarely with catenary wires and contact wires rigidly anchored; more often with catenary and contact wires counterweighted with a system of automatic regulation of the tension (viz. Hungary and Germany); or with ordinary wires anchored and contact wires counterweighted (viz. Algeria and Italy). Each of these types is suitable for either of the two systems of electric traction. The choice of overhead systems is completely independent of the electric traction system and, on the contrary, depends upon the speed of trains, from the lay-out of railway lines, and from the effects of climatic conditions.

7. — *Mechanical stability of overhead supply system.*

For its own mechanical stability, the overhead supply system must be adequately proportioned, in the wires, in the insulators, in the length of the bay and in the supporting structures.

As for the wires, it is well-known that the poor mechanical properties of copper — the only material adopted practically for contact wires — discourage its use in the catenary wires (with great economy in weight) as far as this is permitted by the requirements in connection with the drop in voltage.

From Appendix 9, it will be seen that many railway systems entrust the mechanical functions of longitudinal suspension to bronze catenary wires (the S.N.C.F. on all their 1 500 V D.C. overhead supply system, Holland on their 1 500 V D.C. overhead system on secondary tracks; the S.N.C.B. on all their 3 000 V D.C. overhead supply system; Morocco does the same; the D.B. on all their single-phase, 16.66-cycle, A.C. system; the Belgian Congo on all their single-phase, 50-cycle, A.C. current system; the S.N.C.F. on their principal tracks electrified with single-phase, 50 cycle A.C.); thus a notable economy can be seen in the construction of the lines (for example, on the 1 500 V D.C. system of the S.N.C.F. the lines equipped with the so-called « normal catenary type » (i.e. not « reinforced ») have a copper section of 318 sq. mm, equal, that is, to that normally used by the F.S.) Rarer is the use of steel catenary wires (R.E.N.F.E. on the Ujo-Busdongo line, 3 000 V D.C., and the S.N.C.F. on the secondary and shunting lines of their single-phase, 50-cycle A.C. system).

The lines in copper only are :

a) 1 500 V D.C. :

Madrid-Segovia of the R.E.N.F.E (392-509 sq. mm + feeder).

The principal lines of the Dutch Railways (350 sq. mm + feeder).

b) 3 000 V D.C. :

Leon-Ponferrada of the R.E.N.F.E. (367 sq. mm + feeder).

The F.S. railway system (320 sq. mm).

c) Single-phase 16.66-cycle, A.C. :

The S.B.B. railway system (214-155 sq. mm).

The B.L.S. railway system (177 sq. mm).

The technique of construction of the insulators today gives every assurance regarding the resistance to the tension of the conductors, so that no difference arises in this connection between the various systems.

As for the choice of length of bay one must distinguish the case of the straight way from the curves. For the latter (besides the problems relative to mechanical stresses in common with the straight way and aggravated by the component of the tension of the wires due to the angle of the polygon, in accordance with which the overhead supply system is laid out), there are also the geometrical problems imposed by the sliding contact, which alone may require the use of short bays or of special supports, between those at the two ends of the bay, having the function of giving the desired shape to the polygon. All this is to a large measure independent of the system of electric traction so that all adopt lengths of bay on curves which vary little from each other, as will be seen from Appendix No. 11. It is worth remembering at this point that to small (acute) angles in the above-mentioned polygon correspond — besides the strong centripetal components of the wire tension — also great widths in the sliding contacts of the pantographs (dimension measured at right angles to the track axis and parallel to rail level).

In the straight way, the choice of bay can be made on the basis of normal economic principles, that is attempting to find the lowest cost of installations calculated bearing in mind that, if this cost decreases with the increase in the length of bay, by reducing the number of supports per unit of length, on the other hand it increases with the increase in the length of bay by reason of the greater height and more robust dimensions which must be given to the supports and other parts subject to mechanical stresses which increase with the bay.

We thus come to underline the condition of disadvantage in which the direct current system finds itself — especially at the lower voltages — in connection with many problems of the overhead supply system. It is remembered, however, that the bay in the straight way cannot be increased beyond certain limits imposed by the necessity of limiting the transversal movement of the overhead supply system dependent upon the force of the wind and upon the dynamic action caused by the fast movement of the pantographs of the locomotives. In fact, one would run the risk of compromising the stability of collection, especially if the extensions of movements in a transversal direction, of the slides (more probable and wider the greater the speed of the locomotive) are added to those of the contact wire. All this not only places an upper limit to the maximum bay in the straight way, but in particular circumstances may require such a transverse rigidity of the overhead supply system as to impose very limited bays and constructions of a particular nature. In practice the various limits are such that even with the highest voltages and lightest lines of the single-phase system, normally bays are adopted which are no longer than those already reached in connection with the 3 000 V D.C. system. From examination of Appendix 11, it will be seen that normally the bay in the straight way is approximately 60-63 metres, whilst exceptions, longer (Germany, Holland) or shorter (Spain, Switserland) may be found quite independent of the system.

As far as supporting structures and their concrete foundations are concerned, it is evident that their strength and weight grow with the increase of the tension and weight of the wires which they support, so that the disadvantage of the direct current system shews itself again — especially with 1 500 volts — both for the supports in the straight way and for those on a curve, where, with an equal bay they are subjected to higher angle forces.

On double track lines the problem is raised of the advisability or otherwise of making the two overhead supply systems mechanically independent. The solution mostly adopted is that of total independence; but there are notable examples of the abandonment of this traditional, safe, but certainly expensive technique. Mechanical independence has been given up, for example, by the Dutch Railways where the intense traffic, comprising numerous trains, has not had to suffer any reduction in quality as a result. Some networks (for example R.E.N.F.E.) foresee the possibility of giving up electrical independence by joining the two overhead supply systems in parallel; this, in helping to reduce the drops in voltage, can improve the operational conditions of any system.

8. — *Minimum clearances between live and earthed apparatus.*

As has already been shewn, the value of the voltage in the overhead supply system has repercussions on its construction also insofar as the clearances are concerned which must be left between the live wires and the surrounding non-insulated structures. This question has been the subject of a recent interesting examination in view, above all, of the use of the standard-frequency single-phase system. It is, in fact, known that the requirements of greater clearances between the contact wire and the gauge limit of the rolling stock and between the catenary wires and the non-insulated supporting structures necessarily give rise to more serious difficulties in tunnels, on metal lattice bridges and in general in any passage beneath an overhead structure. In this connection the minimum distance measured at right angles to the rail level allowed between the gauge limit of the rolling stock and the lowest non-insulated part is significant. In fact, within this distance — in the worst conditions — must be located the overhead supply system and the pantograph, the latter being in the position of minimum extension from the normal position of rest.

The data contained in Appendix 12 are not sufficient to obtain this distance, as the minimum between the catenary wire and contact wire is missing. In view of the fact, however, that, for each type of catenary system, this is not influenced by the electric traction system and can thus be considered as equal for all, the sum of the minimum distance between the contact wire and the gauge limit and of the minimum clearance between live conductors and non-insulated surrounding parts (elements which are contained in the above-mentioned Appendix No. 12) may be considered as representative of the difference, in this connection, in each system. The result of this sum shews that the lowest value (300 mm) applies to the 1 500 V, D.C. system (Madrid-Segovia line of the R.E.N.F.E.); but the same R.E.N.F.E. has the same value on the Leon-Ponferrada line, electrified with 3 000 V D.C.

The highest value (1 500 mm) exists on the single-phase, 50-cycle system of the Belgian Lower Congo line, but the same single-phase system produces a value of 600 mm on the Hungarian Railways and 520 mm on the French line Valenciennes-Thionville, values which are equal to or less than those used on the single-phase low-frequency system. One must not be surprised that on one system there should be such a great difference, as also with the single-phase low-frequency system variation is from 450 mm (of the S.B.B. system) to 900 mm (of the other Swiss network — B.L.S.).

Less noticeable differences prevail with the D.C. system, which vary from the 300 mm already mentioned to 350 mm (Holland) for 1 500 volts to 500 mm (Italy and Morocco) for 3 000 volts.

It must, therefore, be concluded that, roughly, the problem of clearances should not cause substantial differences between the various systems of electric traction.

It is, however, noticed that high voltages in the overhead supply system, bringing with it the use of long bays, gives rise to quite small (acute) angles on the curves and, therefore to quite large contact slides, which fact complicates the problem of clearance in another direction, no longer upwards, but towards the sides of the sliding contact, especially in tunnels. If the introduction of this were such as to not permit a sufficient development in the dimensions of the contact, the advantage which the higher voltage can give in respect of the lightening of the overhead supply system could, to a certain extent, be frustrated. But, as is seen, the length of the bay is in general the same for all systems, so that it can be said that, even in respect of lateral clearance, the higher voltages of the single-phase, standard-frequency system requires only the increase of space between the live apparatus and earth. This means passing from 100-150 mm minimum of D.C. or from 150-300 mm minimum of the single-phase low-frequency system to a minimum of 220-400 mm. From Appendix No. 13, it is seen that the expenses sustained by railway systems electrified with the single-phase standard-frequency system in modifying the work in order to obtain greater clearances have been very moderate and in any case no higher than those met by other systems. This, however, may have been dependent upon particularly favourable circumstances which may not always be found in practice. So that it may definitively be said that this aspect of the employment of higher voltages in the overhead supply system does not present technical difficulties and that its economic consequences can only be valued case by case.

C. — Effects due to the nature of the traction current.

9. — *Disturbances to telecommunications.*

With the one exception of the direct current system, when it makes use of rotary machines for the conversion of the alternating current into direct, all the other cases for all the systems of electric traction, comparison of which is made in this report, the current used for traction generates disturbances in the telecommunication circuits situated in the vicinity of the railway overhead supply system. For this reason these circuits must all be enclosed in cables as shewn in Appendix No. 8.

In the direct current substations with mercury-arc rectifiers some railway networks (Italy, Morocco, Germany for the Wisental Railway — see Appendix No. 18) use filters intended to absorb the harmonics of a higher order generated by the rectifiers; other networks foresee their future installation (for example, the S.N.C.B., R.E.N.F.E for the Leon-Ponferrada line); others do not make use of them and do not expect to do so (Holland, S.N.C.F.).

10. — *Electrolytic corrosion.*

In a comparative examination of the various systems of traction the observation cannot be neglected regarding the consequences which, on the systems operated with direct current, wandering or dispersed currents can cause.

It is well known, in fact, that on the railway lines where the track is used as one of the conductors (generally the negative) the current passes through the rails; but as these are not normally insulated from the earth, a part of the current is dispersed, thus also using the ground as a conductor. If here it encounters a route of very low resistance (as, for example, metal conduits) the current travels along this for the whole or part of its length, and in leaving closes the circuit with the substation through the earth. It is at these exit points that corrosion takes place.

The earth, in fact, must be considered as an ionic electric conductor and its electric conductivity is due prevalently to dampness and to solubility or the ionization of the various salts which it contains; therefore on contact with the metal tubing it acts as an electrolyte, facilitating the formation of corrosion of an electrochemical nature for the electrolytic action of the wandering current at the point at which this leaves the tubing.

As long as the underground network of tubing was limited to water or gas conduits of very low pressure, the question was not considered very deeply as the damage which they sustained did not give rise to serious consequences. But as soon as the network of pipelines and methane gas conduits started to be formed, the problem of corrosion became of considerable importance because, to the economic damage dependent upon the shorter life of the corroded tubing, is added that of the dispersion of valuable liquid and the very great danger due to the loss of inflammable fluids capable of forming an explosive mixture with the air.

The corrosion is not entirely caused by the effect of wandering currents but can also have a cheminal, electrocheminal (because of galvanic action) or microbiological origin; that depending upon the action of wandering currents represents a large percentage of the total.

Numerous studies have been carried out in the various countries to deepen the knowledge of the causes of this phenomenon in order to prepare the most effective measures to combat it. Experience has shewn that buried metallic structures are exempt from corrosion when they are maintained electrically negative in respect to the earth with a relative potential of less than —0.6 V. This fact was carefully studied by means of numerous laboratory tests by the Belgian Professor J.N. POURBAIX who thus arrived at the preparation of his electrocheminal theory which illustrated with corrosion diagrams the behaviour of the more usual heavy metals.

The methods of protection against corrosion are divided into passive defence (for example, special insulated connections, placing in cubicles, careful external protective covering of the tubing, etc.) and active defense measures. These latter include :

a) cathodic protection (*) realized with the employment of reactive anodes, or by inserting the conduit to be protected in an electrochemical chain controlled in such a way that the outside surface of the tubing is always cathodic in respect to the earth with which it is in contact : to this end the conduit itself is maintained at the required voltage by special stations fed by the distribution power lines.

b) electric protection, which employs suitable electric « drainage » having the function of collecting the currents passing through the tubing to be protected, forcing them to close the circuit with the substation not by passing through the outside surface of the tubing to the earth (which causes corrosion), but by means of a special circuit formed by insulated metallic conductors.

The limits imposed upon this report prevent us from entering into greater detail on this subject which is of notable size and complexity. How much this has become of present interest and how it affects the economic business life of concerns operating pipe lines or methane gas conduits can

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(*) It is welcome to remember at this point that the fundamental idea of cathodic protection was preconceived by Sir Humphrey DAVY as far back as 1823 for the protection of the copper linings of his vessels.

be illustrated by the following details which are quoted here for information.

According to recent statistics, in the U.S.A. corrosion of buried tubing produces 200 million dollars' worth of damage annually.

The « Régie Autonome du Pétrole Français », according to elements provided by the esteemed Engineer Jean CALLAIS, has calculated that the costs for the above-mentioned protection of their pipe lines correspond to 0.7 % of the total value of the installations themselves which represents the sum of 270 000 Swiss francs; whilst the maintenance costs total 45 000 Swiss francs per annum, equal to approximately 54 Swiss francs per km of conduit per annum.

In Italy, the Azienda Metanodotti Padani, as Engineer Ferdinando BOTTEGLIA has communicated in his memorandum, have carried out a complex system of protection, the installation cost of which has been valued at 0.352 % of the total of the investments, with an annual maintenance cost equal to 100 Swiss fr. per km of conduit.

Still in Italy, the Società Nazionale Metanodotti with the object of combatting the parasite currents, in addition to putting electric protection into operation wherever the state of the ground indicated its necessity, has put to the study the very newest type of synthetic resin coverings which should have noticeably higher mechanical and electrical characteristics than the bituminous coverings used up to now.

All this total of provision and resultant expenses brings, there is no doubt, a sensible lengthening of the life of the tubing which is thus protected also from the other causes of corrosion. So that in the economic account of the concern operating pipe lines or methane gas conduits such expenses can be generally considered productive and remunerative, bringing a diminishing of the annual installation replacement quota. There is no-one that will not see how, in a more general economic picture, at least that considerable part, which can be considered the direct consequence of the presence of railway operation with direct current, must be placed among the negative economic factors of this system of traction.

In consequence of the same wandering currents the cables for the telecommunication circuit, as mentioned in the preceding parag. 9, must also be provided with special protection to reduce the damage of electrolytic corrosion.

A calculation aimed at translating into figures the incidence of all this expense on the total first installation and operating costs of a direct current installation would be difficult; but the scholar who wishes to make a complete technical comparison between the different systems of traction cannot avoid dwelling on this element which cannot be neglected.

D. — Rolling stock.

11. — *General observations.*

The technical comparison between the systems of electric traction under examination leads us now to consider the characteristics and qualities of the locomotives and electric motor coaches which can be constructed with each system and if they are all equally suitable for the modern requirements of railway traction.

Among these, that of drawing heavy trains may be considered well expressed in synthesis by the maximum working drawbar load, which, by international convention, has recently been raised from 20 to 30 tons. This value of drawbar effort is only reached at the moment of starting, when the part concerning the locomotive is practically negligible. Therefore — taking into account the considerable uncertainty regarding the factor of adhesion in relation to the conditions of the wheel flange/rail contact — no great error will be committed in assuming that the minimum adhesive weight is given by the relation between the maximum drawbar working load and the permissible factor of adhesion.

As shewn in Appendices Nos. 20 to 26, this latter does not vary much from system to power, its maximum value being between 1'26 and 1'41 which, for these drawbar efforts, means a minimum adhesive weight of between 64 and 121 tons.

Also the requirement of high speed is typical of modern railway traction and the recent trend to make the entire weight as adhesive weight is worth noting. This has been possible thanks to the constructional improvements which have been adopted to ensure the better distribution of the weight over the axles even under the most difficult dynamic conditions, which has made it possible to entrust to one axle the contemporary functions of guiding and traction. Thus locomotives have been obtained which adapt themselves better to mixed traffic (that is for both heavy and fast trains), which fact normally permits a more intense availability and consequent reduction of the stock.

These results have been achieved by all the systems of electric traction, with the one slight reserve for what will be said about the single-phase standard frequency system.

From this it follows that the adhesive weight of the modern locomotive is also, in general, the total weight.

Replies to the questionnaire regarding the locomotives have been collated in the Appendices Nos. 29-36 attempting to make as wide a comparative analysis as possible of the different locomotives of the four systems. However, as the details have not been presented in an uniform manner by the various railway systems, a work of elaboration has been necessary which, in some cases, had to be based on results, more or less likely, comparisons so that it is not surprising that some of the details collected are liable to better definition. To the extent to which they can be considered as correct they permit several observations of a certain interest.

§ 2 — Specific power.

The first of these observations is concerned with the notion of specific power expressed, for example, in HP per ton, which is quite variable from system to system.

And in view of the fact that the increase in specific power is considered, not wrongly, as an indication of the progress in constructional technique, one could be induced in this way to draw the conclusion of the clear superiority of the single-phase low frequency system over all the others. This conclusion would be correct if the comparison had to take into account the specific power as an element in itself. But it is not like that, and a more accurate examination of the question can clarify this point.

It is well known, in fact, that a power curve, and thus a specific power curve, chosen at random, cannot be given to every locomotive as this must necessarily respect the limit imposed by adhesion. The specific power curve is defined by the product of the speed and the corresponding effort at the limit of adhesion. If this is calculated in relation to the adhesive weight unit (for example, 1 ton), one then has the curve representing the limit of specific power.

In view of the fact that for any speed, this cannot be exceeded, all constructional trends which are intended to utilise adhesion to the full and to raise the specific power must aim at raising the speed of maximum power, which is equivalent to increasing the normal running speed of the locomotive. It must, therefore, be foreseen that such an unsatisfactory trend affects, above all, the locomotives designed for passenger service only, whilst increase in high specific power diminishes for mixed or freight locomotives. This is confirmed by fact. From the Appendices quoted, it appears that the highest specific powers apply for all systems to the passenger locomotives, and in view of the fact that for the 3 000 V D.C. and single-phase 50-cycle systems — by the railway networks to which this report refers — only mixed or freight locomotives are considered, with the exception of two types of passenger locomotives, it follows that the maximum specific power of these two systems appears to be lower.

in absolute value, than that of the other two.

If, however, locomotives destined in all the systems for mixed traffic are compared among themselves, the differences are noticeably reduced.

In fact, the following maximum values are recorded :

— maximum specific power, 1-h rating, of mixed traffic locomotives :

	HP per ton
1 500 V D.C.	25 - 40
3 000 V D.C.	29 - 35
16.66 cycle A.C.	39 - 61
50 cycle A.C.	31 - 53

— maximum specific power, 1-h rating, for freight locomotives :

	HP per ton
1 500 V D.C.	none in existence
3 000 V D.C.	23 (only example, Morocco)
16.66 cycle A.C.	37
50 cycle A.C.	20 - 35

It has been said reduced, not disappeared — and the difference which remains is dependent upon the traction systems. The single-phase low-frequency system which, as opposed to the standard frequency system, makes exclusive use of the commutator type motor, is that for which, to the highest running speeds always correspond the best operating conditions due to the improvement of the power factor and above all of the commutation of the motors and thus of the working conditions of the commutator. Operation with this system not only counts on reaching this ideal operating condition but also on high acceleration to reduce the time during which the operation of the locomotive is far from such condition. This clearly explains the substantial interest in being able to reach such high specific powers.

In the D.C. locomotives the increase of the speed at which maximum power is developed (referring to that at full field) tends, with all other conditions being equal, to increase the time during which the rheostat remains inserted, which fact can give rise to complications for the disposal of the heat generated.

13. — *Different techniques of the single-phase standard frequency system.*

The single-phase 50-cycle system presents itself in an unusual light because, from the point of view of the rolling stock, it does not make use of one technique only, but can make use of more than one and the locomotives thus differently constructed may all run on the same line. It is well known, in fact, that these locomotives may use as traction motors both the single-phase commutator type and direct current motors or the three-phase asynchronous type, the current collected from the overhead supply system being transformed beforehand as necessary.

It does not appear to be advisable at this point to go into a detailed technical examination of the various solutions, all of which, if fairly well known as far as the ideas upon which they are based are concerned, are unknown from the point of view of operational results as their practical realisation is relatively recent (for some solutions it is absolutely « in fieri »).

As far as the use of single-phase 50-cycle commutator type motors is concerned, the French experiment in Upper Savoy, which has followed and completed the previous German efforts on the Höllental, has clearly shewn what are at the present time the possibilities of practical use which it offers. But the limited time elapsed between the commencement of the service with electric traction on the Annecy line and even more the nature of the traffic, which certainly is not that of a main line, leaves many uncertainties closely connected with the regularity and economy of operation which many hope to be able to go into more deeply when the system will be extended to more exacting lines. It is probable that the single-phase 50-cycle electrification of the Bas-Congo - Katanga line and of the Lancaster-Morecambe-Heysham line of British Railways, which have thus put into operation the opinion of the Cock Commission, 1951, can be attributed to this desire to obtain first hand knowledge of the intrinsic qualities of this system. It is a fact, however, that for the projected French electrification of the Valenciennes-Thionville line (where the S.N.C.F. intend to have « Les plus gros trains de marchandises » (*), locomotives with single-phase commutator type motors have been excluded just from this service of the above-mentioned « biggest trains ». And if one takes into account how much M. GARRAUD justly writes in the article mentioned about the interest which exists — at least for certain services — in increasing the composition of the trains at the expense of acceleration, one must conclude that, in spite of some optimistic assurances, these commutator type motors also need big acceleration and speed.

Locomotives finding themselves in a better condition are those with direct current traction motors fed through mercury-arc rectifiers, both multi-anode and single-anode (of the latter type both the ordinary and « Ignitron » types).

These machines, however, present realisation difficulties because of the size of the electrical equipment and their services, and also, especially the Ignitron type, due to the disturbances which they cause to the telecommunications circuits (**), so much so that the S.N.C.F. have limited to five the number of locomotives of this type ordered for the Valenciennes-Thionville line.

It follows that, for heavy trains the single-phase 50-cycle system seems for the present to be directed towards the use of locomotives with direct current traction motors (fed by rotary converters) or with three-phase alternating current traction motors of the asynchronous induction type (also fed through rotary phase and frequency converters).

14. — *Locomotives with several electric energy transformations.*

The critical position of some experts is known towards the construction of locomotives in which numerous energy transformations are carried out before arriving at the final phase of passing from electrical to mechanical, which is their ultimate object.

One of these criticisms regards the necessity of having to install many times the power necessary in the last transformation and — for each of the preceding transformations — increased according to the respective efficiency.

Multiplying these then, one with the other, in the end gives a low total efficiency. The locomotives are, therefore, of a considerable weight and of low efficiency.

This was also the vision which many had in the past when on this basis they judged and condemned both the single-phase system — for the presence of the transformer — and the locomotives with individual axle drive which were said to have a lower efficiency than those having only one or two motors.

Today we know that this judgement must be modified. Even if we do not want to consider that no locomotive exists which, either directly or indirectly, does not require more than one energy transformation (as the rheostat of the D.C. locomotives is not a negligible installed power), one cannot forget that judgements given only on a basis of theoretical grounds of this sort can, as a result of practical experience, undergo substantial modifications. If, in fact, the technical appliances used for the successive transformations do not require

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(*) GARRAUD : Notions techniques générales sur la traction par courant monophasé 50 Hz in « L'électrification des chemins de fer », Ed. *Science et Industrie*.

(**) A. E. MULLER & CORBELLINI : « Considerazioni sulla trazione elettrica con corrente monofase a 50 Hz derivata dalla rete industriale » in the *Ingegneria Ferroviaria,* December 1951; also GARRAUD.

excessive weights (or if they do not reduce unreasonably the specific power and do not unreasonably increase the number of axles necessary to support the locomotive) and if they are not accompanied by great constructional or operational complications, there is no reason to reject them on principle, but it is worth valuing their advantages and disadvantages.

As for efficiency, this is obviously valued, not as a miraculous virtue in itself, but in face of the economic consequences. If there existed a miraculous appliance which had an unitarian efficiency but consumed gold florins, it would obviously have no practical interest.

In the same way, if the saving obtained by improving the efficiency brought about a 50 % decrease in the cost of power, but only a 5 % saving in the total operating costs; whilst on the contrary, by adopting other locomotives, although of lower efficiency, one could reach, for example, a 10 % saving on the total operating costs, it is obvious that the locomotive with the lower efficiency would be preferable. Equally it does not seem that these criticisms have real prejudicial value which some people have of locomotives with several energy transformations because they believe that it is definitely preferable to entrust the locomotive with only the last transformation (from electrical to mechanical) and reserve all the previous ones for the permanent feeder installations. The criticism which some people have of these locomotives, to which they give the name of « mobile substations » loses its sting if one reflects on the success of the « mobile power station locomotives ». In the allocation of the electric traction plant and of its various parts it can be convenient to allocate certain function (power transformation) to the fixed installations or to the locomotive according to the economic consequences arising therefrom and according to the interest one has in finding the cheapest solution. If, for example, attributing the above mentioned transformatory functions to the fixed installations, the cost of 100 of an electrification is divided into 30 for the installations and 70 for the locomotives : and instead, transferring into the latter a part of the function of the former, the cost of the fixed installations is reduced, for example, by 50 %; the two solutions are — as far as the electrification's initial costs are concerned — equivalent if the cost of the locomotives of the second type is 21 % higher than that of the first; wherever such cost increases in a greater or lesser measure the first or second solution respectively would be the more convenient.

In general, it can be expected that the lower the number of trains (and thus, with equal traffic, the greater their weight) the lower is the number of locomotives required and the total investment connected with them; the greater, therefore, is the importance of the investments connected with the fixed installations and the savings which concern them. It seems correct, therefore, to state that within the limits in which the various technical solutions are interchangeable, the choice of the most appropriate belongs to concrete economic judgement, comparing the major burden for the locomotives with the saving in the installations both as far as the initial installation cost and the operating cost are concerned.

15. — *Single-phase locomotives with D.C. traction motors.*

Locomotives with D.C. traction motors fed by rotary converters do not constitute a novelty. In fact, historical considerations apart, the first railway line electrified experimentally by the « Oerlikon » with single-phase standard frequency current at 15 000 volts was the Seebach-Affoltern line, opened to operation with electric traction on 18th November, 1904, using one 600 HP BoBo locomotive weighing 48 tons (specific power 16.7 HP per ton) with rotary converters for the feed of the D.C. traction motors; in actual fact far better proof than that far-off and quickly abandoned experience is that vast experience of diesel-electric locomotives, the electrical equipment of which falls entirely within the single-phase type of locomotive in question. The operation in these, however, is rendered more difficult — when the converter was a synchronous motor, for the benefits which this machine has from the point of view of power factor — because of the necessity of synchronism with the frequency and corresponding in phase with the feed current in the overhead supply system, which can in practice be compromised not only by the accidental break of contact between the pantograph and the contact wire, but also by passing under a section insulator. These latter which separate zones of the overhead supply system which are fed by power sources which, — although interconnected — are different, constitute real interruptions in the operation of the locomotives and in order to reestablish them, more or less complicated electrical controls are necessary. One cannot say, therefore, that mature experience in the operation of diesel-electrics covers all the technical problems created by these locomotives with rotary converters. And, in view of the fact that very little sure information is known about them, a complete judgement can only be postponed.

No less important are the considerations relative to their weight, or better to the number of axles necessary and to the specific power, even more so since experience in diesel-electrics can, in this direction, be considered discouraging. The projects of the S.N.C.F. for the 65 units destined for the freight service on the Thionville line shew us locomotives which can be contained within the maximum European wheel arrangement of the total adhesion types (CoCo) and in the maximum weight per axle, but which, within these limits, give only 20 HP per ton, maximum specific power. It is thus clearly seen that at the present state of affairs, these locomotives lend themselves to the traction of heavy slow trains, that is, freight service; one can say, in fact to a great freight service as represented by the Valenciennes-Thionville line; that is, to a service which is the exact opposite of that required by the single-phase commutator type motors.

The question raised is to know if the use of these locomotives would be equally advisable if, instead of such a heavy freight service, they were destined for mixed traffic : the reply would probably be negative. But it must not be forgotten that the composition of freight trains is — in a far greater measure than passenger trains — dependent upon the manner in which operation is organized. If this can be effected with fewer trains, each heavier than those normally used with the other locomotives, the single-phase machines with which we are concerned would even be usefully selected for their traction, provided that their use were well assured. If, instead, these possibilities did not exist, the use of a stock of locomotives with such outstanding freight characteristics could compromise the advantages of the great utilisation reached with the widely used mixed traffic locomotive.

16. — *Single-phase locomotives with asynchronous three-phase motors.*

Single-phase locomotives using asynchronous three-phase traction motors rouse great interest. The truly daring technique of these locomotives is well known — in its layout principles — both for the solution to a limited number of economic characteristics (Hungary) and for that, not yet realised, with the continuous frequency control (and equally, the voltage) of the traction motor field. Both solutions — and especially the second — are not a little complicated and share with those already named D.C. motors some worrying aspects to which they add some others such as that connected with the necessity of reducing the difference in practice between the diameter of the driving wheels. But — and here is one of their attractive points — they record far lower weights than those with direct current motors. The Hungarian locomotive, with a total adhesion wheel arrangement (BoCo) of unusal type and intermediate among those normally used in Europe and with a lower weight per axle (18 instead of 20 tons) gives a maximum power which is double that of the single-phase/direct current type locomotive of the S.N.C.F. already mentioned, reaching a specific power of over 53 HP per ton, which puts it among the first of all the traction systems. The French single-phase/three-phase locomotive, 20 units of which have been ordered for the Thionville line, even with the greater complexity of its electrical circuit, is not too far from the values reached by its Hungarian sister : with a weight equal to the single-phase/direct current type locomotive mentioned and with the same wheel arrangement, it gives a maximum power which is little less than double and a specific power of 35 HP per ton. Although destined for freight service by the S.N.C.F., if its mechanical characteristics do not impede it (which, according to the latest literature, does not seem likely) it could well be included among the locomotives destined for mixed traffic.

This is not the only valuable asset of this locomotive, there being at least another two of outstanding interest : the possibility of using regenerative braking without further constructional complications; and that of having the wheels of the locomotive connected by the motor feed frequency which constitutes a harmless connecting rod, because non-mechanical, but no less effective and provident, thanks also to the beneficial elasticity permitted by this coupling.

17. — *The question of the ideal mechanical characteristics for traction.*

We now come to consider another question of no little interest and closely tied to the choice of system : that of the mechanical characteristics in the fluctuation of the speed, both of the tractive effort and of the power. It is well known that the commutator type traction motors, both direct current and single-phase alternating current, if fed with a constant voltage at the terminals have a stable characteristic of effort (which thus decreases with the increase in speed). The steeper this decrease the more the power decreases. The gradient of the effort curve is variable, but in any case it is such that in the whole field of utilization the power continues to decrease with the increase in speed. This unfavourable quality is accompanied by the other benefit of the automatic tendency to bring an end to any sliding of an axle which may have started; which is more marked, efficient and ready the more the effort is reduced by every little increase in speed, that is, in fact, the steeper the characteristic. Naturally, the beneficial quality described above is interesting only in the zone of great effort and in this sense would not be compatible with a characteristic of power more favourably sustained at higher speeds. As for asynchronous three-phase induction traction motors, fed at constant voltage and frequency, they equally give a stable characteristic, but so steep, in the field of normal utilisation, that practically no alteration in speed corresponds to the total possible output of effort, so that the power is practically variable with the same law of effort.

In respect of the aptitude of these traction motors, both commutator and induction type, to invert the direction of the energy and thus act as a brake, all of them lend themselves, the first with some constructional complications and with the necessity of some automatic control, the second without either one or the other, and thus in the simplest way.

Much has been written during the last 20 years on the ideal form which one would like to give to the characteristics of traction. According to several experts (*) the characteristics of the theoretical motor should have the following properties :

a) be perfectly reversible, or better, to have the same characteristics of effort and power in traction and in braking;

b) have a characteristic of effort in the fluctuation of the speed coinciding with that at the limit of adhesion : this would give rise to a power characteristic increasing with the speed;

(*) Cfr. Corbellini, Prof. G. : Lessons of transport technique and Economy at the Politecnico of Milan.

c) have the possibility of realising at the driver's will, and for any of the possible speeds of the tractive unit, the constant speed characteristics in relation to each of which the power varies with the same law of effort, in each case both one and the other remaining within the maximum limits imposed by adhesion.

A lay-out thus made — which has its origin in the idea of an always full use of adhesion and of permitting at the same time the control of the train's running acting directly on the speed, which is the final element of this control — excludes the fact that the installed power would only be used in relation to the maximum speed, or that is, rarely — and thus leaves itself open to criticism. In the particular case of commutator type motors — apart from the practical difficulty of being able to realise also the control of them at constant speed (and Pestarini suggested how to do it for D.C. with the metadynamo type machine) — there would even arise the situation that, with the series-wound type, an installed power designed to use full adhesion at maximum speed, would be excessive at the lower speeds : an absolutely intolerable situation.

The asynchronous three-phase motor fed at constant voltage and frequency even less approaches the required characteristics of the theoretical motor.

The case of the use of these same traction motors in locomotives which transform the characteristics of the current taken from the overhead supply system is quite different.

Experience already gained with D.C. series-wound motors in locomotives fitted with motor generating sets has shewn how, breaking away from the necessity of feeding these at constant voltage, new horizons have been opened as far as the form of the characteristic is concerned. The practical use which has followed has been more concerned with the good utilisation of the installed power rather than forcing that of adhesion to the highest speed obtainable. In other words, constant power has been preferred to increasing power. This brings with it, among other things, the fixing of a speed of maximum power up to which full use is made of adhesion. In these locomotives — the technique of which is giving so much to the growing technique of the single-phase system with electric converter on board — the very moderate limits to which the diesel motor can be overloaded limit the output of the locomotive. On the other hand, the regulation of the equipment with direct current traction motors at constant power is criticised by some as being incapable of using their outstanding capacity for overloading. This criticism is certainly founded; but it can diminish in importance if one reflects that this capacity in the use of constant voltage feed can be practically used only in the low speed zone, in that as soon as the motors are left free to run according to their natural characteristics they regulate themselves according to their characteristics with such a law as to reduce, as has been said, the power with the increase in speed and vice-versa. It then happens that, keeping them to a constant power, that power which is lost by the fact of having to give up the overload in the lower speed zone with constant voltage feed, is gained in the remaining field of utilisation.

In the locomotives with transformations in the type of current on board, one can think of obtaining the most convenient characteristic, seeing that the control of the converter machinery permits it; the problem is now led back to that of obtaining certain results in relation to the constructional and operational complications which they require.

In the single-phase — as opposed to the diesel-electrics — for the fact that the first motor of the rotary converter (and even better if it concerns static machinery) is electric and thus, to a certain extent, may itself be overloaded, one may think of also carrying out, if necessary, the control at increasing power required by adhesion. If the motors are asynchronous three-phase fed at variable frequency, it becomes possible to realize all the characteristics of the theoretical motor, thus obtaining the possibility of using at will and to the full either adhesion or installed power, or constant speed on any gradient, or electric braking. If these prospects are put together with the results, even though not yet perfectly defined, of the prototypes realised and of present operation, one cannot but recognise the great interest which these possibilities present for the future application of electric traction.

18. — *The use of electric motorcoaches.*

As shewn in Appendices Nos. 21, 23, 25 and 26, all the systems of traction, — with the exception of single-phase standard frequency — make use of electric motorcoaches not only for local passenger services but also for the long distance high speed trains. On some railway systems (such as Holland, Italy, Germany and Switzerland), they are more widely used; on others (for example, France and Belgium) less so. (Note that the S.N.C.F. has given information regarding only one type of electric motorcoach for 1 500 V D.C.)

For single-phase standard frequency current, the only example of electric motorcoach mentioned in the reply to the questionnaire is the Z 9051 of the S.N.C.F. which, as is known, is a prototype, in fact a test bench for one of the motors under experiment for these types of material (*).

On the other hand, the Hungarians give no information on 50-cycle electric motorcoaches. It is therefore evident that with this system the electric motorcoach is not yet up to standard. It does not seem opportune in this report either to attempt to make forecasts or to repeat what is already known from the technical literature. It will, instead, be interesting to listen at the Congress from the direct voice of those who have dedicated themselves to it, the illustration of the results achieved and the difficulties encountered. The only affirmation which it seems opportune to make here is that a system of electric traction would not be acceptable today to a modern railway system if it did not permit the operation of electric motorcoaches suitable for the two types of traffic already mentioned for which this type of rolling stock is normally destined. Traction experts, therefore, are waiting to know what the new system can give in this field; even more so as the high acceleration and high speeds requested make one think that in this the commutator type motor should find satisfactory use.

19. — *Operational technical requirements.*

The machines, the motors and the equipment used in the different systems of electric traction, although they are all able to satisfy the needs of rail operation, do not, however, have the same behaviour, so that each one, according to its own peculiarities, needs particular and more or less onerous precautions, with considerable and different consequences. All these, definitely speaking, are summed up — as a final result — in maintenance and availability. The first gives rise directly to one of the most important items in the operating cost; the second, limiting the use of the locomotive or electric motorcoach, increases the size of the stock necessary to cover all services, which is translated in greater immobilisation and therefore, in a further increase in operating cost.

The interest is obvious in using locomotives able to travel as much as possible without interruptions other than those imposed by their utilisation, and such as to be able, to a large extent, to attend to their needs during the limited periods which such utilisation leaves free. It is required, then, that the good working of the tractive units should be made independent to a large extent of the greater or lesser ability of the men to whom it is entrusted; it is required, in actual fact, that drivers of medium preparation and ability should be in a position to normally ensure a high standard of utilization. This is for the reason that whilst the technical progress has given

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(*) Cfr. M. TESSIER : *Les prototypes d'automotrices monophasées à 50 Hz de la S.N.C.F.*, in *Electrification des Chemins de fer*. Ed. *Science et Industrie.*

the locomotive, in an ever increasing measure, the capability of remaining in service without interruptions for considerably long periods, on the contrary the progress of civilisation tends to make men less tied down by their work; so that the need is always becoming more accentuated of entrusting one locomotive to several drivers successively, and — for the good utilization of both — to make the turns of duty of the locomotive independent of these of the men.

All these requirements, which operating engineers consider essential and decisive for the goodness of a system — much more than the utilisation of adhesion, than the reduction of weight per horse power, than the outputs and the ideal mechanical characteristic (which things are considered the elegant hobby of the planners) — one normally thinks, can be much better met by simple locomotives than by complex ones. Here lies the inborn diffidence towards the « difficult », towards those solutions which, in order to achieve certain improvements, introduce certain constructional complications. This is the road which leads straight to direct current motors and to transmissions with nose-suspended motors.

From this point of view the single-phase commutator type motor fed at low frequency already constitutes a problem, rendered even more complicated by the advisability of using less inflexible transmissions than those of the tram type. If then one passes to consider the complicated and, above all, delicate standard frequency motor or the « mobile sub-station locomotives », this diffidence for many, becomes hostility. One cannot but recognise the seduction of the simple things, but one cannot forget the imperfection which accompanies excessive simplicity. The same D.C. locomotive has had to complicate itself. When we have arrived at the use, not always simple, of the regulation of the field; at the use of modern rheostats with automatic control, which can, with the failure of one contact, upset the regularity of service of a powerful locomotive. This control is far away from that — simple but brutal — obtained with the minimum number of notches. We have arrived at the use of transmission with fully suspended motors, anything but simple, especially if applied to electric motorcoaches for which the flexibility of suspension (as travel comfort requires) and the difference between the weights when full and empty is considerable. One cannot but recognise that the tractive units normally accepted in modern operation would not in the past have been accepted, being considered too complicated. This brings us to consider just how great the progress of technology of mounting and of the perfecting of delicate mechanisms has been : it also brings us, therefore, to have greater faith in the more complicated solutions. It therefore seems just that the unconditional and preconceived love of the « simple » — which has subjective content — must be replaced by that, much better balanced and justified, for everything which succeeds in satisfactorily overcoming the proof of operation. It is experience which must lead. The electric traction experts have already learnt from this that the wide regulation of the field, the individual axle drive, multi-motored motor units, with many commutators and brushes, the automatic controller, electric braking (obtained from commutator type motors which in traction are series-excited), multiple unit control, thermo-electric sets on board the locomotives and the wide use of automatic controls are not insurmountable complications and that the benefits obtained from them are worth the sacrifice which is made on the altar of simplicity. Experience will also tell them what they want to know today. That is, if the complications which new techniques intend to propose will be equally surmountable, if the advantages which they hope to draw from them will be fully obtained and if they will be worth the sacrifice of the undeniable greater complications.

As shewn in the Appendices already quoted, the availability of the locomotives and electric motor coaches varies for all the systems (with the exception of the single-phase 50-cycle) from a minimum of 82 %

(Holland) to a maximum of 96 % (S.N.C.F.), all the values being independent of the system. For the single-phase 50-cycle system only two details exist relative to prototypes.

It follows that — whilst for the single-phase 50-cycle system there remains only to wait for the results of the very recent or future electrifications — for the other systems it can be said that the availability is practically equal for all, in the sense that one can expect between different locomotives of one and the same system and even of one and the same railway network, differences no less important than those existing between locomotives of different systems. This means that — apart from the cost which each system encounters to obtain this result — from the technical point of view they are equivalent in this respect.

CHAPTER IV.

ECONOMIC EXAMINATION OF THE SYSTEMS OF ELECTRIC TRACTION.

1. — *General observations.*

The economic consequences of the technical characteristics of the systems of electric traction already examined concern the size of the investment necessary to electrify and that of the operating cost. In view of the fact that in this report we want to compare the various systems, it is not necessary to take into account all the investments necessary for an electrification, nor all the elements which make up the running costs of a railway with electric traction : it is obviously sufficient to take into account only those which differ from system to system.

In the investments, distinction is made between those covering fixed installations and those covering rolling stock. The first include the low-frequency power stations, the stations connecting the low-frequency high-voltage lines with others at standard frequency; the high-voltage lines for carrying the low-frequency power (all installations which are not equally necessary for both the systems of electric traction under examination), the overhead supply system feeder substations (which, in the two systems are different from the point of view of number and type) and the overhead supply system (even these differ).

As far as the operating cost is concerned, the elements to take into account are the following : the onus of the interest payable on the capital invested; that for the replacement of the installations and rolling stock together with the maintenance costs of both; the cost of energy and the staff which can be considered as variable between one system and another. Instead the financial depreciation is not included in the operating costs; this on the basis of the principles recently approved by the « Groupe de travail des prix de revient et des plans comptables » of the European Economic Commission (Transport Division).

2. — *The prices contained in the replies to the questionnaire.*

The Railway Administrations which have replied to the questionnaire have expressed the costs of the different parts connected with electrification in the currency of the countries to which they belong. As already stated in parag. 5 of Chapter I of this report, all these prices have been transformed into Swiss francs and in this currency unit entered in the Appendices. The examination of these shews that the prices are far more variable from country to country for one system than they are from system to system in one country. And in view of the fact that this second case — which would have given us a better comparison of the cost of the various systems — is unfortunately less frequent and less conclusive (because each country generally uses one single system for the main lines, the other systems either being absent or relegated to secondary lines with light traffic, or in an experimental stage, or being abolished), it follows that such a comparison cannot be made on safe grounds. On the other hand, the difference in costs in the different countries depends upon many elements, some of which are connected with the size and nature of the traffic, others with the surrounding technical and economic situation : the whole is bound by such complex relations that one cannot hope to separate the different causes and value the weight which each has had in determining the cost. The comparison of the final costs expressed in Swiss francs on its own is, therefore, without any interest. In fact the fixed installations give the following results (see Appendix No. 36) :

a) The least expensive installation is the single-phase low-frequency of the D.B. : 96 660 Sw. frs. per km;

b) The single-phase standard frequency installation of the Valenciennes-Thionville line costs 118 119 Sw. frs. per km, just a little less than the 3 000 V D.C. in Italy (120 962 Sw. frs. per km) whilst the single-phase 50-cycle installation of the Bas-Congo - Katanga Railway costs more (123,161 Sw. frs. per km);

c) The 1 500 V D.C. installations cost 153 327 Sw. frs per km in Holland and 270 668 (with normal catenary system) or 301 048 (with reinforced catenary system) in France;

d) The 3 000 V D.C. installations cost 120 962 Sw. frs. per km in Italy and 195 250 in Belgium;

e) Belgium, for her 3 000 V D.C. installations encounters a cost (195 250 Sw. frs. per km) which is higher than that which her neighbour incurs (153 327 Sw. frs. per km) for her 1 500 V D.C. lines.

All these costs refer to 1 km of one track of double track line and for the single-phase low-frequency system do not include costs relative to the production and distribution of low-frequency power to the sub-stations.

The technical characteristics of the above-mentioned lines are indicated in Appendices 9, 15 and 16; the corresponding costs in Appendices 14 and 19.

As for the locomotives, the lowest cost per unit of weight (8.56 Sw. frs. per kg) and per unit of power (166 Sw. frs. per one-hour rating HP) both belong to the 3 000 V D.C. system, to the F.S. and R.E.N. F.E. respectively. The corresponding highest values (16.27 Sw. frs. per kg and 570 Sw. frs. per HP) both belong to the 1 500 V D.C. system and to the S.N.C.F.

In addition :

For the 1 500 V D.C. system the lowest costs are in Holland (9.12 Sw. frs. per kg and 215 Sw. frs. per HP);

For the 3 000 V D.C. system the highest costs are in Morocco (11.02 Sw. frs. per kg and 443 Sw. frs. per HP);

For the single-phase low-frequency A.C. system the costs vary from 9.15 Sw. frs. per kg (B.L.S.) to 15 Sw. frs. per kg (S.B.B.) and from 181 Sw. frs. per HP (D.B.) to 365 Sw. frs. per HP (S.B.B.);

For the single-phase 50-cycle A.C. system the costs vary from 10.90 Sw. frs. per kg (single-phase A.C./direct current locomotive with rotary converter) to 13.07 Sw. frs. per kg (locomotive with commutator type motors) and from 260 Sw. frs. per HP (locomotive with Ignitron) to 545 Sw. frs. per HP (for the same single-phase A.C./direct current locomotives which record the lowest cost per kg) all of the S.N.C.F.

The technical characteristics and corresponding costs are shewn in Appendices from 20 to 35.

It is therefore evident that the economic results obtained by each Railway Administration are not transferable in the same measure to the others; and that each one must apply considerations of a general order to its own particular case if it wishes to know what would be the result of the adoption of any one system of electric traction.

3. — *Consequences of the repartition of the investments between fixed installations and traction rolling stock.*

The installation cost of an electrification can be considered as subdivided, as has been said, into the two parts concerning the fixed installations and the rolling stock.

In Chapter III, it has been seen that the two systems of electric traction under examination and the different ways in which they can be realized all have the singularity that the more they gain in simplicity of the fixed installations the more they lose in the complexity of the tractive units. One finds then that passing from the 1 500 V D.C. or from the 3 000 V, D.C. to the single-phase 16.66 or to the 50-cycle, the costs per km of the overhead supply system and the substations decrease (for the single-phase 16.66-cycle system, however, the requirements of the low-frequency feed system must be taken into account), whilst in general, the cost of the tractive units increases.

In general, the increase in cost of each tractive unit is not so important as the reduction which is obtained in the cost of the fixed installations. It should be observed, however, that the size of the latter may vary with the variation of the traffic (and especially of the number of trains) in a far more discontinuous manner than the rolling stock. In other words, one and the same fixed installation can be well adapted to a very variable number of trains and thus tractive units forming the stock. One gathers therefore, that there exists for each line or railway system a condition of minimum in the repartition of costs between the fixed installations and the rolling stock, within the vicinity of which slightly different repartitions would produce a relatively small variation in the total cost. It follows that if the traffic to be dealt with requires a stock consisting of a large number of tractive units, so that their cost constitutes the predominating part of the total cost of electrification, then even quite noticeable savings in the installation costs (equally if accompanied by even small increases in the cost of the tractive units) lead to negligible reductions in the total cost. If, on the contrary, the traffic can be dealt with by a few tractive units, even though considerably more expensive, each important reduction in the cost of the fixed installations will have considerable effect on the total cost. Ing. **CORBELLINI** Junior (*) examined the problem by studying the application, to an imaginary double-track uphill railway of 750 km of 3 000 V D.C., single-phase 16.66-cycle and single-phase 50-cycle systems for three different types of traffic. From the particular cases examined in this study (which considers installation costs higher than those given in the replies to the questionnaire by the countries to which this report refers), it results that for electrification with 3 000 V D.C. the installation cost varies from 50 % to 75 % of the total cost of electrification; for the single-phase 16.66-cycle system (for which, however, the special low-frequency feeder installations were not taken into account) it varies from 33 % to 66 %; for the 50-cycle, from 30 % to 62 %. It is seen, therefore, how variable can be the savings which can be made with a single percentage réduction of the installation cost.

On the basis of the costs obtained in reply to the questionnaire, corrected according to reliable principles, but not free from either uncertainties or, to a certain extent, from arbitrary subjective valuations, the University of Pisa has made a calculation, on very broad lines, of the cost of electrifying the Milan-Venice line (today served by steam) both with the practically unified system in Italy of 3 000 V D.C. and with single-phase 50-cycle, adopting for the latter the technical elements which have been made known in recent literature. As the line has intense, but not heavy traffic, covered by numerous trains, the cost of the fixed installations with the 3 000 V D.C. system would represent less than 32 % of the total cost of electrification. As a result of the favourable circumstances which characterize the operation of this line, by adopting the single-phase 50-cycle A.C. system really important savings could be made in the fixed installations compared with the use of the 3 000 V D.C. system, to the order of more than 57 %, whilst the increase in the cost of the locomotives has been estimated to the extent, certainly not excessive, of 14 %. The final result, however, is a saving of barely 9 % of the total cost of the electrification. If, instead, with the same installations half the number of traction units circulated, a difference between the two systems of 22 % of the above-mentioned total would be calculated. All this,

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(*) MULLER e F. CORBELLINI : « Considerazioni sulla trazione elettrica con corrente monofase a 50 Hz derivata dalla rete industriale », in the *Ingegueria Ferroviaria,* December 1951.

besides, is well known also from practical operation with diesel-electric locomotives, where a 100 % saving on the installations has a greater effect on the total investments for traction the lower the number of locomotives making up the total stock.

It seems, therefore, that one can conclude that the real deciding factor in the choice of the system, from the point of view of the cost of electrification, is the traffic; because if this can be dealt with by a few trains, where necessary heavy, and in any case infrequent, then good economies can be realized in the total cost of electrification, adopting a system which reduces noticeably the cost of the installations, whilst on the contrary, even installations which are relatively more complex will be acceptable.

4. — *Onus of interest on capital invested.*

Let us now examine the different elements of the operating cost already listed in paragr. 1 of this Chapter.

The onus of the interest on the capital invested is proportional both to the rate of interest (which for each railway network or country is to be considered as constant) and to the size of the amounts invested, that is, the original cost of the fixed installations and the rolling stock.

This onus is independent of the duration of the investments (as it represents the cost of the money invested at the time the investment was made) and is applicable to the total amounts invested. This must not seem to be in contrast to some details shewn in Appendix No. 37 (*). It is shewn, for example, in this document that Holland applies a 4 % rate of interest on the average capital invested; the S.B.B. 4 % on a certain quota of the capital invested which differs according to the installation to which it refers; the S.N.C.B. applies a 5 % rate on the whole capital invested, but for 18 years only. Apart from the obvious consideration that, with the object of comparing the different systems of electric traction, any method whatever of calculating the onus under examination (*) may be considered as good, as they are applied equally to the systems under comparison, it must be pointed out that the differences between the different methods quoted above only originate in the necessity of taking into account — in the calculation of the operating cost — of the « historical part of the cost » : from the fact, that is, that the different investments took place in the past in different periods, with rates of interest, amounts invested, legal bonds and general conditions all different from each other, so that it is, in practice, difficult to take each into account separately in determining the total operating cost. These different methods, however, do not interest the problem of the comparison between the systems of electric traction which can be foreseen for the future operation of a determined line or network. In this case, in fact, it is sufficient to calculate the annual onus applying the rate of interest to the whole amount invested. In conclusion, therefore, the entity of the rate of interest apart, the onus of the interest on the capital invested is directly proportional to it; therefore, the operating cost is also, in this way, directly influenced by the cost of electrification.

5. — *Annual replacement quota.*

Replacement, called by many « technical depreciation » or « industrial depreciation » — is the onus of operation relative to the consumption of the instruments of production. The fundamental conceptions which this onus defines can be thus summarized :

a) The onus of replacement is actually borne by the railway undertaking only at the time when the instrument of production to which it applies (for example, the

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(*) Unfortunately only a small number of railway administrations have replied to part E of the questionnaire which did, in fact, concern the elements of operating cost. They are : S.N.C.B., Holland, S.N.C.F., S.B.B. and B.L.S.

(*) Except, it is understood, every method which arbitrarily increases the onus of the interest on capitals invested in the fixed installations (or in the rolling stock) altering the existing relations between the cost of the two investments.

overhead supply system, the locomotives, etc.) finishes its technical life; it is then represented by the « replacement cost ». The repartition of the onus of replacement on the annual operating cost constitutes the « annual replacement quota »; this is obtained by means of a mere accounting operation which can be made on the basis of any arbitrary law, provided that the condition is respected that the sum of the different quotas reproduces the « replacement cost ». Among these arbitrary laws the following two are particularly remembered :

i) uniform repartition, or constant annual replacement quota;

ii) repartition calculated so that in each financial year the sum of the annual replacement and maintenance quotas remains constant; in this way the annual replacement quota is highest in the first years and decreases with the passage of time.

Finally, it is to be remembered that the « replacement cost » may be constituted, at the end of the life of the instrument, either by the simple sum of the annual quotas set aside or else by including their matured compound interest (in which case the annual quotas would be less).

In Appendix No. 37 it is shewn that the S.B.B. does not take into account this compound interest. The other railway networks indicated in the same appendix do not give any particular information in this connection : it seems, however, that they also work in the same manner. In the same way, none of the networks mentioned above has stated whether the annual quotas are constant or decreasing; it seems, however, that they are constant.

b) As has been said in the preceding paragr. *a*) the annual replacement quota depends upon the life of the instrument and the cost of its replacement. In general, this latter is different from the original cost and variable during the life of the instrument. From this arises the necessity of periodically recalculating the replacement quotas in order to take into account the actual cost of replacement.

The railway networks quoted in Appendix No. 37 have given no information on this subject.

c) In order to be able to calculate the replacement quotas, it is necessary to forecast the life of the instrument. This may be limited by two causes :

i) technical efficiency of the instrument;

ii) technical surpassing by similar instruments of more recent production (obsolescence).

The forecasts pertaining to the second of the above-mentioned causes can be only very approximate because no-one can know with certainty what the future possibilities of technical progress can be. It can only be said that obsolescence is felt differently by the different instruments (for example, electric motor coaches are more subject to it than locomotives and these more than substations; whilst the high voltage substation feeder lines are practically exempt from it); whilst for each one it is more to be feared the longer its technical efficiency lasts.

This latter depends, apart from the intrinsic constructional characteristics of the instrument, also upon the maintenance to which it is subject. It can even be said that, from a strictly technical point of view, maintenance is able to preserve indefinitely in each instrument its original technical efficiency, so that one could think it should be practised until obsolescence overtakes the instrument. But in view of the fact that with the passage of time the cost of maintenance always becomes higher, the moment arrives when the sum of the cost and the replacement quota exceed that relative to a new instrument, compared with which the present one, even if not completely surpassed, always presents a certain technical inferiority. And that is the moment in which the technical life of the instrument can be considered finished.

Also from this point of view, as for obsolescence, the different instruments find themselves in different conditions. There are some, in fact (for example, tunnels) the ordinary maintenance of which assures them eternal life, provided that some destructive event due to force-majeure does not intervene; that is, there are some instruments which do not have to be replaced. In electric traction the power lines probably fall into this category, because the methodical protection of their supporting structures from the elements, the replacement of the insulators and a few lengths of broken conductor wire enable them to be kept in service for a very long time. For the overhead supply system maintenance is heavier than that of the power lines because of the mechanical requirements of the contact; but in actual fact, the problem presents itself in the same way except as far as the contact wire is concerned (although this to a large extent is recovered, re-drawn and used again).

The substation buildings, their electrical apparatus, including the transformers — excluding the conductor cables, the automatic equipment, the rotary converters and the mercury-arc rectifiers — are perhaps to a large extent instruments not requiring replacement. Instead, the tractive units, for which as has been said, obsolescence is to be feared, are subject to replacement. In fact, the efficiency of their use depends upon the form of operation and thus upon the nature of the traffic, which is one of the most changeable characteristics of transport. It may, therefore, happen that certain technical requisites given today at the planning stage may no longer be convenient for future operation well before the end of their technical life.

All the railway systems indicated in Appendix No. 37 give explicitly the length of life of the various instruments for which they calculate replacement, with the exception of the B.L.S. which establishes the replacement quota in percentage value of the cost of the investment (not specified but presumably original cost); from this quota the corresponding life in years is obtained on the supposition that the replacement quota is constant and without interest; and also with the exception — but only insofar as tractive units are concerned — of Holland and the S.B.B. which give no information about them. From the above-mentioned Appendix the following appears :

for the low-frequency power stations (the only detail is that of the S.B.B.) the estimated life is 50 years;

for the high-voltage electric lines it is 40 years according to the S.B.B. and 50 years for all the other railway systems with the exception of Holland which, having all the lines in cables, estimates 25 years;

for the substations, Holland and the S.N.C.F. distinguish the building from the rest and both attribute 25 years of life to the electrical equipment whilst for the building they attribute 33 and 75 years respectively. The other railway systems which have not made the afore-said distinction give substations a life varying from 30 to 50 years;

for the overhead supply system, Holland distinguishes the contact wire from the rest and gives a life of 12 and 40 years respectively; the other railway networks, which have not made this distinction, give a life for the complete system of 40 to 60 years;

for the tractive units, the details vary from 33 to 45 years without distinction between electric motorcoaches and locomotives.

The observation which immediately springs from the reading of the afore-cited figures is that these durations of life are so long compared with the experience we have of electric traction that no-one can think that they are the result of that experience. They are more often the fruit of an effort of fantasy encouraged by the necessity of accountancy of calculating the replacement quota. It is probable that, with the exception of particular cases or special events, many of the durations of life indicated will have to be modified by the practical results. Personally we maintain that a large part of the fixed installations of electric traction can be included in the total of instruments « not to be replaced » especially if one considers that in many cases the maintenance cost remains constant for a long time or increases to a very limited degree, even if improvements, which intelligent maintenance fatally brings with it, are included.

i) for direct current : the necessity of having recourse to more complicated substations (especially for 3 000 V) when regenerative braking with the return of power to the high voltage feeder network is required to be adopted; the dangers and complications connected with defence against electrolytic corrosion, especially in the case in which this affects tubing of explosive or high-value fluids;

ii) for single-phase low-frequency alternating current : the necessity of having either complicated frequency converter substations or a special system of low frequency feed suitable for railway use only;

iii) for single-phase standard frequency alternating current : liabilities arising out of unbalanced single phase charges collected from the high voltage three-phase power lines : constructional complications of the locomotives, both with commutator type motors and with machines transforming the type of current; the absence for the present, of sufficient experience, especially of electric motor coaches;

iv) for all systems : the necessity of having adequate protection against disturbances to the telecommunications.

All the afore-said technical reserves are waiting to be dissolved by experience and progress. This applies, above all, to the single-phase standard frequency system which still has to leave the experimental stage; this will take place with the opening to operation of the Valenciennes-Thionville line of the S.N.C.F. which is therefore eagerly awaited by the experts. But also the other systems of traction count on freeing themselves from their deficiencies as quoted above, and it is from the perfection of the mercury-arc rectifier that the D.C. system is waiting to be able, with a simple mechanism, to return power to the feeder power lines and the single-phase low-frequency system to be connected directly to the public distribution power line by means of substations converting phase and frequency without rotary machines.

b) The different systems quoted above have the singularity that the simpler and cheaper their fixed installations, the more complicated and expensive are their tractive units. The programme of electric traction has been developed, however, in the sense of accepting the simplicity and economy of the fixed installations and forcing itself to reduce the complications and cost of the corresponding tractive units.

c) With the increase in traffic, the increase necessary in the tractive unit stock and in the size of the fixed installations do not follow the same law. In fact both of these variations are non-continuous, but the lack of continuity is greater for the fixed installations than for the rolling stock. It follows that the nature of the traffic, and above all the possibility of its being served by few trains is decisive of the importance which the saving which can be obtained in the cost of the fixed installations. has on the total cost of electrification.

d) The operating cost is to a very limited degree dependent upon the cost of electrification. It can therefore happen that on a system for which the cost of electrification is high, the operating cost may be moderate. This cost tends to increase with the increase of the rolling stock and with the delicacy of the tractive units and substation machinery.

2. — *Inter-running between lines having different systems of electric traction.*

The use of electric traction raises the problem of the inter-running of trains between railway networks having different systems of electric traction. This concerns both circulation within the area of one network and that between lines of different networks and it presents itself in different forms according to whether it concerns lines belonging to networks already electrified or to be electrified.

If the lines belong to different networks of which at least one has not yet carried out an important electrification, then if no particular difficulties arise, it is convenient to extend the same system of electrification to the second network, naturally on the condition that it is expected to obtain benefit in sending the tractive units of one network on to the lines of the other.

ADMINISTRATIONS		WESTERN GERMANY	BELGIUM AND COLONY		SPAIN					FRANCE					MOROCCO	ITALY			HOLLAND	SWITZERLAND		OBSERVATIONS
QUESTIONS			Belgium	Bas-Congo to Katanga	Madrid-Segovia (a)	Ujo-Busdongo (b)	Total (a) (b)	Leon-Ponferrada (c)	Total (a) (b) (c)	Paris-Lyon (a)	Paris-Le Mans (b)	Total (a) (b)	Valenciennes-Thionville (c)	Total (a) (b) (c)		D.C. network	Three-phase network	Total		Chemins de fer Féderaux	Chemins de fer des Alpes Bernoises	
A. 5. *Enumerate special operating difficulties, e.g. steep gradients, curves, tunnels, etc., State number and aggregate length of tunnels.*	Maximum gradient	55 ‰	25-30 ‰	12.5 ‰	21 ‰	20 ‰		15-20 ‰		5 ‰	8 ‰		11.5 ‰		15 ‰				13 ‰	60 ‰	27 ‰	
	Minimum radius	150 m		200		300		300		500	700		300							100	300 for main lines 180 for sec. lines	
	Length of tunnels (km)	None			8.22	25.5	33.7	5.96	39.66	12.350		12.350	3.951	16.301	2.80	174 s. track 104 d. track	119.6 s. track 51 d. track	293.6 s. track 155 d. track	None	111 s. track 64 d. track	41	
A. 6. *Train-kilometres passenger service per annum worked electrically.*		(1)	4 958 579	Negligible	2 305 217	158 049	2 463 266	563 268 (2)	3 026 534	14 315 000 (3)	4 043 000 (3)	18 358 000 (3)	1 216 000	19 574 000	1 815 000		–	66 069 051	30 589 652	48 381 345	3 160 822	1) The German Railways have given a combined passenger and freight figure
A. 8. *Passenger service* (a) *Gross ton-km per annum.*			1 538 371 000	Negligible	2 395 112 436	57 745 764	2 452 858 200	232 817 440 (2)	2 685 675 640									31 098 590 200 (4)	1 752 448 567	10 570 352 791	490 056 576	2) Estimated figure.
(b) *Trailing ton-km per annum.*			1 463 343 000		401 229 800	44 998 300	446 228 100		446 228 100	6 270 618 000 (3)	1 659 000 000 (3)	7 929 618 000 (3)	390 122 000	8 319 740 000	484 283 000	-		22 280 207 100 (4)	1 420 581 161			3) Including suburban traffic.
A. 9. *Train-km freight traffic per annum worked electrically.*		40 198 940 (5)	1 120 287	1 250 000 (2)	1 254 454	362 200	1 616 654	1 313 270 (2)	2 929 924	11 029 000	3 720 000	14 749 000	6 464 000	21 213 000	2 721 000	—	—	33 358 650	5 012 356	13 771 349	734 923	4) Both with locomotives and electric motor coaches
A. 11. *Freight traffic* (a) *Gross ton-km per annum.*			1 113 154 000	500 000 000 (2)	862 538 053	151 222 864	1 013 760 917	1 334 179 310 (2)	2 347 940 227						3 176 300 000	—	-	34 247 735 700	3 906 710 378	6 999 790 293	361 206 229	5) This figure refers to passenger and freigth total train-km.
(b) *Trailing ton-km per annum.*			1 012 511 000	254 000 000 (2)	705 142 500	150 817 300	855 959 800	1 064 686 750 (2)	1 920 646 550	9 234 058 000	2 428 000 000	11 662 058 000	6 859 878 000	18 521 936 000	2 339 940 000			26 706 667 500	3 460 682 314	—	—	
	Traffic density determined by ratio between nett. ton-km (freight and pass.) and the actual track route length.	7 980 890		1 227 053 (6)	3 345 540	3 118 082	3 309 240	5 856 360 (2) (7)	4 114 150	9 067 061 (3)	7 540 590 (3)	8 699 670 (3)	8 884 803	8 748 910 (3)	3 701 471			5 625 961 83 464 (8)	1 938 547	4 232 020	3 073 151 (9)	6) Freight traffic only exists. 7) At one time only freight traffic was expected. 8) This figure refers only to ton-km with electric motor coaches.
A. 14. (a) *Total consumption for traction, kWh/per annum.*			74 328 369 (11)		57 529 719	16 030 828	73 560 547	12 634 300 (10)	86 194 847	407 000 000	107 000 000	514 000 000	160 000 000	674 000 000	74 920 440	1 145 350 000	332 625 000	1 477 975 000	450 000 000 (4)	960 000 000	39 494 625	9) This calculation is made on gross ton-km.
A. 15. (a) *Settled policy to proceed with further electrification.*			A programme of electrification of 1 500 km of double track has been studied. A part of this has either been carried out or is in the course of being carried out whilst the remainder will be finished in 1956.		A programme has been drawn up for the electrification of 1 300 km to be carried out in stages according to the possibility of obtaining the necessary materials.					Except for the lines for which specific technical reasons arise, the programmes of electrification depend entirely upon considerations of an economic order. The practical principle adopted is the consumption of coal. The S.N.C.F. feels that electrification with 1 500 V, direct current is convenient when the annual consumption of coal per kilometre of double track exceeds 400-500 tons, whilst for electrification with standard frequency single-phase current this limit is reduced to about 300 tons. In consideration of this fact 3 330 km of line still remain to be electrified in France. The speed of its realization is closely connected with the renewal requirements of the steam locomotive stock.					No	For some time there has existed a vast programme for the continuation of 3 000 V D.C. electrification and for the transformation of installations electrified with three-phase A.C. into D.C. which is in course of realization. At the present time the following lines are in course of electrification Messina-Palermo Messina-Catania Bologna-Venezia Milano-Padova. The programme of future electrifications may be carried out at the rate of 200-400 km per year if financial conditions permit.			The programme of electrification of the main lines will be completed in 1953	The entire network is electrified with the exception of two small frontier sections the electrification of which depends upon the opinion of the neighbouring countries.	No	10) Figure relative only to the Torre Branuelas branch at present electrified at 1 500 V D.C. 11) Including power for heating.
A. 18. *State one or more of the main reasons which governed the choice of system at the time the choice was made.*			At the time of electrification the single-phase system did not have any tested examples of electric motor coaches. On the other hand the application of 3 000 V D.C. with substations of 30-40 km was suited to the layout of the railway system in view of the fact that the most important points had very similar relative distances.	The choice of single-phase current is dependent exclusively upon reasons of an economic order in view of the greater lightness of the overhead supply system, the simplicity of the substations and their great spacing.	The first electrifications were carried out with direct current because at that time direct current motors were clearly superior to the others. At the present time the single phase industrial frequency system may be examined, but this gives rise to the following inconveniences; 1) Locomotives not sufficiently tested; 2) Single-phase current feed causes lack of balance which might be prejudicial to the entire high-voltage distribution system; 3) In view of the severe gradients on the Spanish lines, great expense would arise in consequence of the disturbances created by the greater distances between the overhead supply system and the earth. Therefore, for the reasons stated above it is not considered convenient to change the system not even for the new and future electrifications.					At the time of the first electrifications, 1 500 V direct current was chosen for the following reasons : 1) Superiority of direct current traction motors; 2) Difficulty in using a voltage higher than 1 500 V, in construction of rolling stock especially that destined for suburban traffic: 3) Complications relative to the three-phase system (pantograph, rigid speed, etc.). At present technical progress has made the use of standard frequency single-phase feed possible which presents the great advantage of reducing installation costs by more than one-third without increasing operating costs.					Direct current was chosen because this system seemed to have reached greater perfection and did not necessitate a high-voltage distribution system at special frequency. The voltage of 3 000 V was chosen for economic reasons.	The direct current system avoids the construction of special power stations for railway low-frequency current or the installation of low-frequency generators in existing power stations and the construction of very high voltage power lines specially for the railway frequency, whilst it allows better and easier use of the power which can be produced by standard frequency power stations. In addition there is a lower drop in voltage in the overhead supply system and a greater output whith the use of mercury arc-rectifiers. These reasons are still valid and therefore today the same system would be chosen.			The particular operational conditions in Holland with small transport distances and dense traffic were responsible for the choice of the system which at the time offered the safest type of traction motor.	The choice of single-phase current is dependent upon the following principal motives : 1) possibility of regulating the voltage statically; 2) Large distances between feed points; 3) Lightness of the overhead supply system; 4) Reduction of the intensity of current; 5) Absence of wandering current.		
A. 19. *If you were not influenced by considerations of interrunning with existing electrified lines of your own or neighbouring railways, and could neglect the cost of reequipping your existing electrified lines, would you change the system now in use, and to what other system?*					Generally speaking, no.					This is a purely theoretical hypothesis as the cost of changing the direct current network into single-phase would be much higher than the economy realized by the new system of traction.						Apart from the abolition of the three-phase system, which will be replaced by direct current as funds permit, the F.S. have no intention of carrying out further modifications because they maintain that direct current is the system most adapted to important railway traction as it is the only system compatible with the operational regularity of the feed plants.			One cannot exclude the condition of inter-circulation between the various networks.	This problem does not concern us as the whole network is electrified.	Should other lines be electrified the same system would be adopted.	

If, instead, the two networks to which the two lines belong have both already carried out important electrifications with different systems, three solutions can be foreseen; that of changing the locomotive (and terminating the electric motorcoach service) at the frontier station; or that of using, if possible, « double-system » (i.e. suitable for both systems) locomotives and electric motorcoaches; or finally that of substituting the system of electric traction of one network with that of the other. Between the three, that solution will be preferable which, from all points of view, including the economic, is, case by case, more convenient.

Although it is not possible to make a valid estimate for each case, judging by what occurs in similar circumstances, but relative to lines belonging to the same railway network, it seems that the use of « double-system » machines is the least convenient, whilst the other two solutions are more so; the third, however, is the most expensive.

As, in fact, the standardisation of the system of electric traction between lines of one and the same railway network can bring with it large savings, due above all, to the better utilisation of the tractive units and the consequent reduction in the stock (to which operating cost, as has been said, is very sensitive), however, if a system of electric traction has already been considerably extended, its abandonment and the use of another in its place would generally bring with it an intolerable burden. The S.N.C.F. in its reply to point A 19 of the questionnaire, says « ...the expenses in transforming the D.C. network into single-phase would be higher than the saving which could be realized with the new system of traction ».

If it is like this for lines included in the area of a single railway network, the change of system would be even less convenient when the lines belonged to different networks. For these, therefore, it seems that nothing better can be found than changing the locomotives at the frontier station; unless the technique of « double-system » machines undergoes favourable development in the future, which will take place only if the neighbouring networks find a substantial economic convenience in exchanging tractive units.

3. — Many times it has been written that the single-phase standard frequency system, reducing the initial cost of the fixed installations, lowers the threshold of the traffic intensity beyond which electrification of a line is convenient. Let us ask ourselves the question, then, is we must necessarily give up such electrification for the sake of the advantages of the standardisation of the system when the line for which it would be suitable is included in a network which has already made extensive use of a different system of traction.

Obviously the reply can come only from a balance between the advantages of electrification with the most economical system and the disadvantages of the contemporary existence of two systems of traction. Sometimes, however, operating engineers, — lovers of simplicity at any price — reject the idea of this contemporary existence without even attempting the balance. Instead this can be usefully made, taking care to refer it not to one line, but to a network of lines. If a large railway network can be materially split up into two networks one of which is already electrified with any one system and the other is still to be electrified; and if the two networks have only a limited number of common stations; if also the network to be electrified, for each km of length, serves less traffic than that already electrified, and if the traffic can be served by a limited number of trains; finally if for each of the two networks it is possible to organize the operation in such a way that high utilisation of the tractive units is permitted, it must not be excluded, off-hand, that two systems of electric traction may co-exist in the same railway network. Each definite judgement can only be given after an accurate objective examination. It can suggest that for the network with less traffic the single-phase standard frequency system can be used with satisfaction and good economic advantages.

SECTION A

PARTICULARS OF LINES ALREADY ELECTRIFIED OR IN COURSE OF BEING ELECT

ADMINISTRATIONS	ACTUAL SINGLE TRACK MILEAGES (km)	S			
		DIRECT CURRENT			
		0.5 — 0.85 kV		1.5 kV	3
		Overhead supply system	Conductor rail	Overhead supply system	Ov s sy
(A) *Belgium and Colony* 1. Société Nationale des Chemins de fer Belges	(a) Electrified lines	—	—	—	(1)
	(b) Electrified main tracks	—	—	—	
	(c) Electrified siding and shunting tracks	—	—	—	
2. Société Nationale des Chemins de fer Vicinaux	(a) Electrified lines	(2) 1 486	—	—	
	(b) Electrified main tracks	—	—	—	
	(c) Electrified siding and shunting tracks	—	—	—	
3. Compagnie du Chemin de fer du Bas-Congo au Katanga	(a) Electrified lines	—	—	—	
	(b) Electrified main tracks	—	—	—	
	(c) Electrified siding and shunting tracks	—	—	—	
(B) *France and French Union* 4. Société Nationale des Chemins de fer français	(a) Electrified lines	—	203	4 014	
	(b) Electrified main tracks	—	(5)	(5)	
	(c) Electrified siding and shunting tracks	—	(5)	(5)	
5. Compagnie des Chemins de fer du Maroc	(a) Electrified lines	—	—	—	
	(b) Electrified main tracks	—	—	—	
	(c) Electrified siding and shunting tracks	—	—	—	
(C) *Italy* 6. Ferrovie Italiane dello Stato	(a) Electrified lines	15	—	—	4
	(b) Electrified main tracks	15	—	—	6
	(c) Electrified siding and shunting tracks	—	—	—	3 (
(D) *Netherlands* 7. Nederlandsche Spoorwegen	(a) Electrified lines	—	—	1 299 (7)	
	(b) Electrified main tracks	—	—	2 516	
	(c) Electrified siding and shunting tracks	—	—	584	

Appendix No. 1

E COUNTRIES AND NETWORKS SHEWN UNDER POINT 4 OF CHAPTER I

TRACTION			TOTAL	OBSERVATIONS
SINGLE PHASE		THREE PHASE		
3—25Hz	50 Hz	16 2/3 Hz		
—	—	—	(1) 124.10	(1) and also : 58.7 km being electrified 510.5 km in program of electrification
—	—	—	—	
—	—	—	—	
—	—	—	(2) 1 486.00	(2) suburban lines with tram-type traffic.
—	—	—	—	
—	—	—	—	
—	207	—	207	
—	207	—	207	
—	20	—	20	
(3) 47	—	—	(4) 4 264	(3) at 12 kV. (4) also 110 km D.C. 1.5 kV and 363 km A.C. single phase 50 Hz under electrification, 398 km D.C. 1.5 kV and 881 km A.C. single-phase 50 Hz projected in electrification's programme. (5) reply has been given by the French National Railways (S.N.C.F.) only for the three normal kinds of lines referred to in questionnaire.
(5)	—	—	(5)	
(5)	—	—	(5)	
—	—	—	727	
—	—	—	763	
—	—	—	187	
—	—	1 420	5 765	(6) included shunting tracks 600 V D.C. with overhead supply system.
—	—	1 946	8 580	
—	—	846	3 920	
—	—	—	1 299	(7) also 45 km under construction.
—	—	—	2 516	
—	—	—	584	

SECTION A

PARTICULARS OF LINES ALREADY ELECTRIFIED OR IN COURSE OF BEING ELECTRI

ADMINISTRATIONS	ACTUAL SINGLE TRACK MILEAGES (km)	SYS			
		DIRECT CURRENT			
		0.5 — 0.85 kV		1.5 kV	3
		Overhead supply system	Conductor rail	Overhead supply system	Ove sup sys
(E) *Spain* 8. Réseau National des Chemins de fer Espagnols (R.E.N.F.E.)	(a) Electrified lines	—	—	(8) 200	6
	(b) Electrified main tracks	—	—	331	6
	(c) Electrified siding and shunting tracks	—	—	91	1
(G) *Switzerland* 9. Chemins de fer Fédéraux Suisses	(a) Electrified lines	—	—	—	-
	(b) Electrified main tracks	—	—	—	-
	(c) Electrified siding and shunting tracks	—	—	—	-
10. Chemins de fer des Alpes Bernoises	(a) Electrified lines	—	—	—	-
	(b) Electrified main tracks	—	—	—	-
	(c) Electrified siding and shunting tracks	—	—	—	-
11. Rhaetische Bahn	(a) Electrified lines	—	—	—	
	(b) Electrified main tracks	—	—	—	
	(c) Electrified siding and shunting tracks	—	—	—	
(H) *Hungaria* 12. Hungarian State Railways	(a) Electrified lines	—	—	—	
	(b) Electrified main tracks	—	—	—	
	(c) Electrified siding and shunting tracks	—	—	—	
	Total . . . (a)	1 501	203	5 513	5
	(b)	15	—	2 847	7
	(c)	—	—	675	3

N. B. — German Railways replies are not included in this appendix.

Appendix No 1.

COUNTRIES AND NETWORKS SHEWN UNDER POINT 4 OF CHAPTER I *(continued)*

RACTION			TOTAL	OBSERVATIONS
INGLE PHASE		THREE PHASE		
— 25Hz	50 Hz	16 $^{2}/_{3}$ Hz		
—	—	—	262	(^{8}) also 1 423 km under electrification at 3 000 V D.C.
—	—	—	393	
—	—	—	109	
848	—	—	2 848	(^{9}) 15 kV
048	—	—	4 048	
785	—	—	1 785	
250	—	—	250	(^{10}) 15 kV
277	—	—	277	
105	—	—	105	
277	—	—	277	(^{11}) 11 kV
277	—	—	277	
22.4	—	—	22.4	
—	188	—	188	
—	376	—	376	
—	224	—	224	
422	395	1420	17 697.1	
602	583	1946	—	
912.4	244	846	—	

QUESTION	ALGERIA	BELGIUM (S.N.C.B.)
Appendix No. 3.	3 000 V D.C.	
SECTION B *POWER SUPPLY*		
1. (a) *Do you own the power stations — entirely?*	No	No
(b) *Do you own the power stations — in part?*	No	No
Appendix No. 4.		
5. (a) *Are high voltage feeders necessary to transmit power to substations, and if so, do you own them entirely or in part?*	The substations are fed : 3 directly from the 90 kV line of the Algerian Electricity & Gas Co., 1 directly by the EGA power station at Bone, 1 by the EGA sectional post of Tebessa by means of a 5 500 V power line.	Yes, but they are the property of suppliers.
(b) *State type and length of feeders and how they are arranged.*	—	For 70 kV they are overhead, for lo voltages underground.
(c) *Are feeders used to supply power to consumers outside your own railway, and if so, state how it affects your railway technically and commercially?*	—	In some cases they serve only the way substations, in some others, other users.

ITALY (F.S.)	MOROCCO	SPAIN	
		Ujo-Busdongo	Leon-Ponferrada
3 000 V D.C.			
No	No	No	No
Only partially	No	No	No
and all are the property he F.S.	The railway is fed by the company which distributes power to each of the twelve distribution substations.	Yes	Yes
l length : 8 870 km at 130 kV, at 60 kV, at less than 60 kV. in copper, in aluminium steel, in aluminium alloy, double three-phase system single three-phase system		Three-phase without neutral, with earth wire, in aluminium-steel. 14 km long at 30 kV.	Three-phase, with metal supports and rigid insulators: Al. steel without earth wire. Voltage : 45 kV.
with no technical effect, with supplementary pros.		No	No

QUESTION	SPAIN	NETHERLANDS	FRANCE	
	Madrid-Segovia		Paris-Lyon	Paris-Le Man
Appendix No. 3 *(contin.)* **SECTION B** *POWER SUPPLY*		**1 500 V D.C.**		
1. (a) *Do you own the power stations — entirely?*	No	No	No	No
(b) *Do you own the power stations — in part?*	No	No	No	No
Appendix No. 4 *(contin.)*				
5. (a) *Are high voltage feeders necessary to transmit power to sub-stations, and if so, do you own them entirely or in part?*	Yes	Yes, in ownership.	Yes, in general a connection exists by means of lines owned by the railway with the exception of some particular cases.	(a) 2 substations are fed from the 1 network of the way, the others re power from the work of the Fr Electricity Co.
(b) *State type and length of feeders and how they are arranged.*	Three-phase, without earth wire, without neutral : in Al. steel, 150 km at 45 kV.	2 lines in parallel; average length : 7 km; section : 3 × 95 sq. mm.	The total length of the lines at 60 kV is equivalent to approx. 1 040 km of three-phase line. The lines are made up of three conductors in aluminium-steel of 228 sq. mm section and 1 earth conductor of 93 sq. mm also in aluminium-steel.	(b) The principal c acteristics are : 1) for the 60 kV l copper conductor 94 sq. mm sec 1 earth conducto steel of 60 sq. section. 2) for lines at 90 conductors in minium-steel of sq mm section, e conductor in minium-steel of 8 mm section.
(c) *Are feeders used to supply power to consumers outside your own railway, and if so, state how it affects your railway technically and commercially?*	No	No	Sometimes but in such a way as to avoid every possible inconvenience to railway operation.	(c) Generally, no, sometimes the su is returned to nati production.

FRANCE Valenciennes-Thionville	BAS-CONGO TO KATANGA (C.F.B.C.K.)	HUNGARY	GERMANY (D.B.)	SWITZERLAND (S.B.B.)	SWITZERLAND (B.L.S.)
	A.C. 50 CYCLES			A.C. 16.66 CYCLES	
No	No	Yes	No	Yes, partially. 7 power stations producing 65 % of the total consumption are railway owned.	No
No	No	—	Yes, to a small extent.	Yes. 2 power stations which produce 35 % of the total consumption are owned jointly with industry.	No
(a) Only two substations will need high-voltage lines which will operate at 60 kV and will be connected to the nearest points of the French Electricity Co. They will be a few km in length.	Yes	The substations are connected to the national public distribution network by means of single-phase connections a few km in length.	Yes, all railway owned.	Yes, a large part railway owned.	Yes, partially railway owned.
	Two feeders at 25 kV respectively 2 and 3 km in length. One feeder at 120 kV 4.5 km in length.	—	—	Total length 1 250 km at 33, 66 and 132 kV.	Trellis and Differdinger pylons. Length : 6.5, 2.5 and 11.5 km.
No, they will feed only the substations.	No	—	No	Generally no, except for particular cases with economic benefits to the railway administration.	—

QUESTION	ALGERIA	BELGIUM (S.N.C.B.)
Appendix No. 5		**3 000 V D.C.**
7. (a) *If you buy power, state tariff as fully as possible as at January 1st, 1953, and how price is restricted by law. How does the price compare with that charged for industrial supplies? In particular state :*	—	The tariff takes many factors intc account, such as : 1) Index of the prices per minute, 2) Price of 1 ton of coal, 3) Average workman's salary, etc.
(c) *If you take a lagging wattless current or cause unbalance, are you penalised for doing so, and how?*	—	No penalties are foreseen.
(d) *If you can supply leading wattless current or regenerated power, on what terms can you sell it to the Supply Authority?*	—	—
Appendix No. 6		
8. *What restrictions are placed on you with regard to :*		
(a) *interference with wave form of supply?*	—	None
(b) *power factor?*	—	None
(c) *negative phase sequence currents?*	—	All possible steps are taken to eliminate the effects of wandering currents.

ITALY (F.S.)	MOROCCO	SPAIN	
		Ujo-Busdongo	Leon-Ponferrada
3 000 V D.C.			
Different tariffs according to the characteristics of collection.	Binomial formula : (a) 19.13 Sw. fr. per kVA calculated on 60 points, (b) 10 cents per kW-h.	Up to 1st January 1953, 1.3 cents per kW-h. A revision of the tariffs is at present in course.	Up to 1st January 1953, 1.3 cents per kW-h. A revision of the tariffs is at present in course.
The problem does not arise. On the still existent three-phase network, to take into account the greater losses which are verified for the diminution of cos φ the quantity of active power withdrawn with cos $\varphi < 0.6$ is increased by a % of 0.6 for each 1/100th part of deficiency of cos φ.	The question does not arise.	Suppliers obliged to produce gratis 620 kW-h reactive for each 1 000 kW-h watted consumed.	Not yet foreseen.
No unbalanced absorptions are encountered.	Never realized.	Subtracted from that consumed in traction.	When it will exist, it will be deducted from that used for traction.
Of little importance.	None	As for 1 500 V D.C.	None
See 7, *c*, for three-phase system.	None	—	None
Various forms of protection of special importance for the methane and oil conduits.	No legislation exists on this subject.	—	None

QUESTION	SPAIN	NETHERLANDS	FRANCE	
	Madrid-Segovia		Paris-Lyon	Paris-Le Mans
Appendix No. 5 *(contin.)*		**1 500 V D.C.**		
7. (a) *If you buy power, state tariff as fully as possible as at January 1st, 1953, and how price is restricted by law. How does the price compare with that charged for industrial supplies? In particular state :*	As for the 3 000 V lines	The tariff in use is trinomial : (a) 5 450 Sw. frs. per annum per feed point. (b) 27.25 Sw. frs. per annum per kW of power available at each feed point. (c) 2 + 0.08 (K - 10) cents per kW-h where K = price of 1 ton of coal.	Different tariffs according to season, hour and geographical situation. Average in 1953 : 5.8 cents per kW-h.	Different tariffs acc ording to the season hour and geographica situation. Average in 1953 : 5. cents per kW-h.
(c) *If you take a lagging wattless current or cause unbalance, are you penalised for doing so, and how?*		The load is not unbalanced.	No penalties.	No penalties.
(d) *If you can supply leading wattless current or regenerated power, on what terms can you sell it to the Supply Authority?*		Not supplied.		
Appendix No. 6 *(contin.)*				
8. *What restrictions are placed on you with regard to :* (a) *interference with wave form of supply?*	None	None	None for the moment.	None for the momen
(b) *power factor?*	—	None	—	—
(c) *negative phase sequence currents?*	The return circuit is maintained in the best possible conditions of insulation.	Two legislative regulations exist. 1) The increase in electrical resistance caused by the track joints must not exceed 25 %. 2) The resistance of a rail 1 m in length, including the joint must not exceed that of a plain rail 10 m in length.	—	—

FRANCE	BAS-CONGO TO KATANGA (C.F.B.C.K.)	HUNGARY	GERMANY (D.B.)	SWITZERLAND (S.B.B.)	SWITZERLAND (B.L.S.)
Valenciennes-Thionville					
	A.C. 50 CYCLES			**A.C. 16.66 CYCLES**	
As for D.C.	—	The national public distribution network makes electric power available to the railway at a better price than to the other consumers.		The tariff is binomial : (a) Power tax from 28 to 40 fr. per annum per kW installed. (b) consumpt. tax : 1) Summer : from 5 to 23 h : 1.75 ÷ 2.5 cents per kW-h; from 23 to 5 h : 1.6 ÷ 2 c. per kW-h. 2) Winter : from 5 to 23 h : 3.5 ÷ 4 c. p. kW-h. from 23 to 5 h : 2.8 ÷ 3.5 c.p. kW-h. This tariff applies to an average cos φ of 0.75.	In Summer : 5 cents per kW-h. In Winter : 6 cents per kW-h.
As for D.C.	Prohibited to exceed an unbalance of greater than 2.5 %.	No, our power factor is very good; and our single-phase load does not cause unbalance other than as permitted in the public distribution network.	—		No
As for D.C.	—	The good power factor of the phase converter system of traction is taken into consideration in the price of electric power. Regenerated current is measured by the meters.	—	The supplement of reactive power, if requested, is paid at 0.15 cents in the Summer and 0.25 cents in the Winter. Regenerative braking in use, and the current regenerated is absorbed in the network.	No indemnity.
None r the moment.	None	Such difficulties do not exist with the single-phase 50-cycle system.	Agreements are made with the suppliers and the other concerns interested in order to reduce all possible inconveniences	None	—
—	None	—	—	None as long as the fictitious power derived from it remains within the limits of the installed power.	Power factor greater than 0.8.
	None	–	—	None	—

QUESTION	ALGERIA	BELGIUM (S.N.C.B.)
Appendix No. 7 SECTION C **Overhead line and fixed track equipment.**	3 000 V D.C.	
1. *For what voltage drop do you design the train equipments :* (a) *Normal,* (b) *Emergency,* (c) *Do you allow large drops on branch lines? If so, by how much?*	— — —	9 % 18 % —
Appendix No. 8		
6. (a) *Are open wire telecommunication circuits altered, e.g. cabled after lines are electrified? If so, why?*	—	Yes, passing them into cables to avo inductions, danger to the staff, and avoid the construction of new ov head lines.
(b) *If so, are costs charged against cost of electrification?*	—	Yes
Appendix No. 9 **Overhead line.** 8. *What is material, size, and arrangement of overhead contact system :*		
(a) *Main lines?*	Double inclined catenary : steel : 79 sq. mm, copper : 107 sq. mm, aluminium : 400 — 500 with connections to the catenary : every 250 m. In tunnels polygonal catenary is used.	(a) Main lines : (1) bronze : 94 sq. mm, (1) copper : 104 — 72, (2) copper : 100 sq. mm × 2.
(b) *Branch lines?*		(b) Secondary lines : (1) bronze : 94 sq. mm, (2) copper : 100 sq. mm × 2.
(c) *Sidings or shunting tracks?*	Simple catenary : steel : 53.7 sq. mm, copper : 107 sq. mm	(c) Sidings : (1) bronze : 94 sq. mm, (2) copper : 100 sq. mm.

INDEX :
(1) catenary wire.
(2) contact wires.
(3) feeder.

ITALY (F.S.)	MOROCCO	SPAIN	
		Ujo-Busdongo	Leon-Ponferrada
3 000 V D.C.			
25 % 37 % -	22 % — No	12 % 34 % 15 %	12 % 34 % 15 %
es, substituted by under- round cables to avoid acci- ental contact with high vol- ge wires and to reduce duction phenomena.	In some zones, yes, upon the application of tele-control.	No	Yes, they have been placed in operation outside the zone of railway influence.
No	Partly.	—	Yes
) Main lines : atenary with longitudinal spension : (1) (2) (1) copper : 120 sq. mm, (2) copper : 100 sq. mm × 2) Secondary lines and sid- gs : (1) (2) (1) copper : 65 sq. mm, (2) copper : 100 sq. mm.	(a) and (b) Simple catenary for main and secondary lines: (1) (2) (1) bronze : 94 sq. mm, (2) copper : 107 sq. mm × 2 (c) Sidings: (1) (2) (1) bronze : 54 sq. mm, (2) copper : 107 sq. mm.	(a), (b) and (c) Polygonal : (1) steel : 88 sq. mm, (3) feeder, copper : 107 sq. mm, (2) copper: 107 sq.mm × 2.	(a) Main lines polygonal : (1) (2) (3) (1) copper : 153 sq. mm, (3) feeder, copper : 225 or 153 sq. mm, (2) copper : 107 sq. mm × 2 (b) Secondary lines : (1) copper : 153 sq. mm, (2) copper : 107 sq. mm, (c) Sidings : tram suspension with one wire only.

QUESTION	SPAIN	NETHERLANDS	FRANCE	
	Madrid-Segovia		Paris-Lyon	Paris-Le Man
Appendix No. 7 *(contin.)* **SECTION C** **Overhead line and fixed track equipment.**	**1 500 V D. C.**			
1. *For what voltage drop do you design the train equipments :* (a) *Normal,*	20 %	10 %	17 %	17 %
(b) *Emergency,*	50 %	—	34 %	34 %
(c) *Do you allow large drops on branch lines? If so, by how much?*	15 %	± 20 %	—	—
Appendix No. 8 *(contin.)* 6. (a) *Are open wire telecommunication circuits altered, e.g. cabled after lines are electrified? If so, why?*	No	Yes, with cables to avoid disturbances.	Yes, they have been placed in underground cables.	Yes, they have placed in undergro cables.
(b) *If so, are costs charged against cost of electrification?*	—	Yes	Yes	Yes
Appendix No. 9 *(contin.)* **Overhead lines.**				
8. *What is material, size, and arrangement of overhead contact system :* (a) *Main lines?*	(a) Main lines : (1) copper : 299 sq. mm, 182 sq. mm, (3) feeder copper : 228, 210 or 152 sq. mm, (2) copper : 105 sq. mm × 2.	(a) Main lines: (1) (2) (3) (1) copper : 150 sq. mm, (3) feeder, copper : 150 sq. mm, (2) copper : 100 sq. mm. × 2	(a) Main lines : 1) reinforced catenary : (1) bronze : 116 sq. mm, (3) copper : 143 sq. mm, (2) copper : 150 sq. mm × 2. 2) normal catenary : (1) bronze : 116 sq. mm, (3) copper : 104 sq. mm, (2) copper : 107 sq. mm × 2.	(a) Main lines : 1) reinforced caten (1) bronze : 116 sq. mm, (3) copper : 143 sq. mm, (2) copper : 150 sq. mm × 2) normal catena (1) bronze : 116 sq. mm, (3) copper : 104 sq. mm, (2) copper : 107 sq. mm. ×
(b) *Branch lines?*	(b) and (c) Secondary lines and sidings, (1) copper : 182 sq. mm, (2) copper : 105 sq. mm.	(b) Sidings : (1) (2) (1) bronze : 70 sq. mm, (2) copper : 100 sq. mm × 2.	(b) Secondary lines : 1) simple catenary : (1) bronze : 116 sq. mm, (2) copper : 107 sq. mm × 2. 2) Light catenary : (1) bronze : 65 sq. mm, (2) copper : 107 sq. mm,	(b) Secondary line 1) simple catenary (1) bronze : 116 sq. mm, (2) copper : 107 sq. mm × 2) light catenary : (1) bronze : 65 sq. mm, (2) copper : 107 sq. mm.
(c) *Sidings or shunting tracks?*			(c) sidings : (2) copper : 107 sq. mm.	(c) sidings : (2) copper : 107 sq. mm.

INDEX :
(1) catenary wire.
(2) contact wires.
(3) feeder.

FRANCE	BAS-CONGO TO KATANGA	HUNGARY	GERMANY	SWITZERLAND	SWITZERLAND
Valenciennes-Thionville	(C.F.B.C.K.)		(D.B.)	(S.B.B.)	(B.L.S.)
	A.C. 50 CYCLES			A.C. 16.66 CYCLES	
24 % 30 % —	32 % 32 % 32 %	15.6 % 21.9 % Yes, 9.2 %	15 % to 20 % 30 % —	— 15 % Max 20 %	10 % 30 % No
es, in cables to rotect the circuits rom electric influ- nce and reduce lectromagnetic in- luction. Yes	Yes, placing them in underground cables to avoid electromagnetic induction. Yes.	Yes, they have been placed in cables to avoid disturbances and danger. Yes	Yes, transforming the telephone lines into cables. No	Yes, in cables. Partially.	Yes, to eliminate wandering currents. Yes
a) Main lines: (1) (2) (1) bronze : 65 sq. mm, (2) copper : 107 sq. mm.	(a), (b) and (c) : (1) bronze : 84 sq. mm, (2) copper : 107 sq. mm.	(a) : (1) steel or bronze : 50 sq. mm, (2) electrolytic copper- 100 sq. mm. Polygonal catenary with automatic tension equipment both for the contact wire and catenary wires.	(a), (b) and (c) : (1) bronze : 50 sq. mm (2) copper : 100 sq mm	copper : (1) 107 sq. mm	Electrolytic copper : (1) 107 sq. mm
b) Secondary lines: (1) (2) (1) stainless steel: 30 sq. mm, (1) normal steel: 48 sq. mm, (2) copper : 107 sq. mm.		(b) —		copper : (2) 85 sq. mm	do. (2) 70 sq. mm
c) sidings : (1) (2) (1) normal steel: 48 sq. mm, (2) copper : 107 sq. mm.		(c) Catenary with fixed supporting wire mounted on transversal suspension. (1) steel or bronze: 50 sq. mm, (2) electrolytic copper : 65 sq. mm.		copper : 70-107 sq. mm (1) copper : 107 sq. mm (2) 70 sq. mm	

QUESTION	ALGERIA	BELGIUM (S.N.C.B.)
Appendix No. 10	**3 000 V D.C.**	
9. *What types of construction are used for the supports :* (a) *Single track,* (b) *Two tracks,* (c) *Multiple tracks.* *State also for main lines, branch lines and sidings where the construction differs.*	Contact wires and feeders are supported by chains of three insulators suspended from brackets fixed to sectional iron pylons, mounted on concrete blocks, having four standard heights.	Poles with brackets or rigid portals.
(d) *Have you provided mechanical and electrical independence of tracks? If so, how has it been obtained, particularly at junctions?*	—	Yes, electrically by means of section insulators.
Appendix No. 11		
10. *What is the average distance apart of structures?*	—	63 m in the straightway.
Appendix No. 12		
12. (a) *What are the average and minimum permitted clearances between live metal and earthed metal or other structures? and*	—	150 mm
(b) *between minimum height of contact wire and clearance gauge of rolling stock?*	—	200 mm

ITALY (F.S.)	MOROCCO	SPAIN	
		Ujo-Busdongo	Leon-Ponferrada
	3 000 V D.C.		
bular or flat trellis poles.	Brackets supported by pylons or porticos.	Metal columns with supports.	Metal columns with supports trellis portals.
		No double tracks exist.	
ectrical separation of the ntact wires or sectioned by earances. racks electrically and mech- ically independent.	Yes, on the double tracks by means of sectional insulators.	Generally, yes, in the stations only electrically.	Generally yes, in the stations only electrically.
m in the straightway. m in windy areas. to 40 m on curves accord- g to the radius.	63 m in the straightway.	46 m in the straightway and on curves of up to 950 m radius. 30 m on curves of less than 950 m radius. 27 m in tunnels.	60 m in the straightway. 30 to 50 m on curves.
average 200 mm min. 150 mm	250 mm	150 mm	average 300 mm minimum 100 mm
350 mm	250 mm	200 mm	200 mm

QUESTION	SPAIN	NETHERLANDS	FRANCE	
	Madrid-Segovia		Paris-Lyon	Paris-Le Mans
Appendix No. 10 *(contin.)*		**1 500**	**V D.C.**	
9. *What types of construction are used for supports :* (a) *Single track,* (b) *Two tracks,* (c) *Multiple tracks.* *State also for main lines, branch lines and sidings where the construction differs.*	Metal poles or trellis portals.	Poles or portals in iron.	Bracket supports or rigid girder portals. Re-inforced concrete supports have been experimented with, they are heavier and more fragile than those in iron and therefore their transport is more expensive. However, their maintenance does not incur any expense. Their cost is higher than the girder supports whilst it is equal to trellis supports.	Bracket supports rigid girder por Re-inforced conc supports have b experimented w they are heavier more fragile than tl in iron and there their transport is n expensive. Howe their maintenance c not incur any expe Their cost is hig than the girder t whilst it is equal trellis supports.
(d) *Have you provided mechanical and electrical independence of tracks? If so, how has it been obtained, particularly at junctions?*	Generally yes, in the stations only electrically.	Yes, only electrically.	Only the contact wires are made independent at the connections both with air space circuit breakers and with section insulators.	Only the contact w are made indepenc at the connecti both with air sp circuit breakers with section insulat
Appendix No. 11 *(contin.)*				
10. *What is the average distance apart of structures?*	50 m in the straightway. 30 to 40 m on curves. 20 to 25 m in tunnels.	70 m on the open line.	63 m in the straightway. 27 m on curves of 350 m radius.	63 m in the straig way. 27 m on curves 350 m radius.
Appendix No. 12 *(contin.)*				
12. (a) *What are the average and minimum permitted clearances between live metal and earthed metal or other structures? and*	100 mm	150 mm	average 300 mm minimum 150 mm	average 300 mı minimum 150 mı
(b) *between minimum height of contact wire and clearance gauge of rolling stock?*	200 mm	200 mm	average 320 mm minimum 170 mm	average 320 mı minimum 170 mı

FRANCE alenciennes-Thionville	BAS-CONGO TO KATANGA (C.F.B.C.K.)	HUNGARY	GERMANY (D.B.)	SWITZERLAND (S.B.B.)	SWITZERLAND (B.L.S.)
	A.C. 50 CYCLES			A.C. 16.66 CYCLES	
ders with wide gle or twin wings	GREY girders with brackets, and rigid portals.	Simple trellis pylons. Trellis pylons with portals.	Generally trellis supporting poles.	Differdinger girders or portals.	Pylons-Differdinger with brackets.
See D.C.	No	Yes, they are separated mechanically and form lines of separate pylons.	Yes, electrically and mechanically by means of individual supporting poles for each point of support.	—	No
63 m in the straightway. 50 m on curves 250 m radius.	60 m in the straightway. 40 to 50 m on curves.	70 m	80 m in the straightway. 65 to 70 m on curves.	Normally 50 m exceptionally 100 m with intermediate supports.	60 m normally 22.5 to 28 m in tunnels.
erage 420 mm imum 220 mm	450 mm	300 mm	minimum 300 mm	average : 250-300 mm minimum : 150-200 mm	600 mm
erage 370 mm imum 300 mm	1 050 mm	300 mm	minimum 300 mm	300 mm	300 mm

QUESTION	ALGERIA	BELGIUM (S.N.C.B.)
Appendix No. 13	3 000 V D.C.	
20. (bi) *Actual total cost of overhead equipment per km of single track in double track line, adjusted to January 1, 1953 prices, of an actual electrified section of line, including all its special work at junctions, sidings, stations, tunnels, etc., —* *including provision of foundations.*	—	57 750 Sw. fr.
Appendix No. 14		
22. (a) *What were the corresponding costs for the actual scheme of altering structures, etc., to obtain the necessary clearances?*	—	—
(b) *Would these costs have been materially increased or decreased if a different system (involving larger or smaller clearances) had been adopted?*	—	—
(c) *If so, by how much, approximately?*	—	—
Appendix No. 15		
3. (a) *What is the theoretically correct spacing of substations?*	—	35 to 40 km
(b) *What is actual average distance apart of substations?*	57.7 km	30 km
(c) *What is actual maximum distance apart of substations?*	80.5 km	41 km

ITALY (F.S.)	MOROCCO	SPAIN	
		Ujo-Busdongo	Leon-Ponferrada
	3 000	V D.C.	
45 240 Sw. fr.	43 400 Sw. fr.	—	7 650 Sw. fr. Estimated detail referring to ground which does not present any special obstacles.
ery limited expenses which ould increase were the erating voltage noticeably gher.	—	40 800 Sw. fr.	—
—	—	—	—
—	—	—	—
40 km	40 km	40 km	40 km
40 km	60 km for the lines with less traffic. 30 km on the lines with more traffic.	42 km	38 km
60 km (exceptional)	84 km	There are only two substations.	41.8 km

QUESTION	SPAIN	NETHERLANDS	FRANCE	
	Madrid-Segovia		Paris-Lyon	Paris-Le Mans
Appendix No. 13 *(contin.)*		1 500	V D.C.	
20. (bi) *Actual total cost of overhead equipment per km of single track in double track line, adjusted to January 1, 1953 prices, of an actual electrified section of line, including all its special work at junctions, sidings, stations, tunnels, etc.,— including provision of foundations.*	—	58 860 Sw. fr. (estimated figure)	Reinforced catenary 90 055 Sw. fr. Simple catenary 74 865 Sw. fr.	Reinforced caten 90 055 Sw. fr. Simple catenar 74 865 Sw. fr.
Appendix No. 14 *(contin.)*				
22. (a) *What were the corresponding costs for the actual scheme of altering structures, etc., to obtain the necessary clearances?*	—	—	These expenses are in the region of 17 % of the cost of the catenary system.	These expenses ar the region of 17 % the cost of the ca ary system.
(b) *Would these costs have been materially increased or decreased if a different system (involving larger or smaller clearances) had been adopted?*	—	—		
(c) *If so, by how much, approximately?*	—	—		
Appendix No. 15 *(contin.)*				
3. (a) *What is the theoretically correct spacing of substations?*	20 km	—	For substations with two converters, one of which is reserve, it is about 17 km	For substations v two converters on which is reserve, i about 17 km
(c) *What is actual average distance apart of substations?*	19.77 km	20 km	Paris-Dijon : 14 to 17.5 km Dijon-Lyon : 8 km	17.5 km
(c) *What is actual maximum distance apart of substations?*	24.8 km	—	Paris-Dijon : 15.5 km Dijon-Lyon : 8.5-20.5 km	20.5 km

FRANCE /alenciennes-Thionville	BAS-CONGO TO KATANGA (C.F.B.C.K.)	HUNGARY	GERMANY (D.B.)	SWITZERLAND (S.B.B.)	SWITZERLAND (B.L.S.)
	A.C. 50 CYCLES			**A.C. 16.66 CYCLES**	
rmal catenary: 0 995 Sw. fr.	49 500 Sw. fr.	of no importance	On open line : 21 813 Sw fr. In stations : 33 711 Sw. fr.	50 to 60 000 Sw. fr.	100 000 Sw. fr.
ese expenses are the region of % of the cost the catenary sys- n.	—	—	From 3 % to 6 % of the total cost of electrification, including the locomotives.	—	—
	—	—	—	—	—
	—	—	—	—	—
pends upon the e of locomotive d, varies from 40-100 km	70 km	50 km	20 km minimum	The geographical disposition of the main points on the railway system has generally decided the position of the sub-stations.	—
62 km	70 km	50 km	50 km		—
74.6 km	70 km	65 km	100 km		32 km

QUESTION	ALGERIA	BELGIUM (S.N.C.B.)
Appendix No. 16	**3 000**	**V D.C.**
26. *What type and size of equipment is installed in substations, and specify any features to which you attach importance.*	There are in all four substations. Of these : (a) two are equipped with a rotary converter of 2 500 kW consisting of a synchronous three-phase (asynchronous starting by means of cage winding) with two D.C. 1.5 kV generators connected in series and fitted with commutation poles together with compensation windings and a compensation winding for regenerative travel. Maintenance of these converters requires specialised staff and is more onerous than static rectifiers. (b) two are equipped with a mercury arc rectifier of 2 000 kW not suitable for regeneration. One of these two substations has also a rheostat for the absorption of regenerated currents.	Normally fitted with two or th mercury arc rectifiers of 3 000 k air-cooled. High-voltage breakers internal pne matic; external pneumatic with l volume of oil. 3 kV; of ultra rapid type. The substations are staffed but te control is not foreseen for the futu substations.

ITALY (F.S.)	MOROCCO	SPAIN	
		Ujo-Busdongo	Leon-Ponferrada
3 000 V D.C.			
itially six-phase rectifiers th 12 anodes, water-cool- : recently six-phase recti- rs with 6 anodes cooled by rced draught. ectifier power 2 000 kW. ne substations are always ffed but tele-controlled d automatic substations e being studied.	The substations with automatic equipment are of two types : (a) rotary converters, synchronous motor D. C. generator (b) mercury arc rectifiers where regeneration is not used. The automatic substations are supervised by a reduced staff. One substation is remote-controlled.	Each substation consists of: two rotary motor generators with corresponding transformers. Each rotary converter consists of : One asynchronous three-phase motor of 1 900 kW; two generators of 750 kW at 1 500 V. The substations are staffed and not remote-controlled.	The substations consist of : One or two 2 000 kW mercury arc rectifiers or three 3 000 kW mercury arc rectifiers. In the Lagrangia substation there is also a mercury arc rectifier inverter for regeneration. The reserve is generally made up of a mobile substation with one rotary converter of 2 000 kW. The substations are not remote controlled and are staffed.

QUESTION	SPAIN	NETHERLANDS	FRANCE	
	Madrid-Segovia		Paris-Lyon	Paris-Le Mans
Appendix No. 16. *(contin.)*		1 500	V D.C.	
26. *What type and size of equipment is installed in substations, and specify any features to which you attach importance.*	The substations consist of : two rotary commutators of 1 500 kW at 750 V with transformers in the open. The substations are not remote-controlled and are staffed.	The substations are of three types : (a) With high-voltage installation in the open with metallic type rectifiers with pump and water and air cooled. Installed power 3 000 kW. (b) High-voltage screened installation transformers in the open; rectifiers as in (a). Installed power 2 400 kW. (c) High-voltage installation screened and with low volume of oil, transformers in the open; air-cooled metallic type rectifiers, installed power 2 400 kW. The substations are not staffed but are remote controlled with two systems : 1) for the lines electrified prior to 1951 from the nearest signal box. 2) for lines electrified after 1951 control is effected by means of a centralised control system which controls 27 substations and 39 section posts by means of 752 controls, 377 danger signals and 1 088 starting and stopping signals.	Paris-Dijon branch, two or three arc-rectifiers of 4 000 kW each with shunt characteristics. Dijon-Lyon branch : one or two arc-rectifiers of 2 000 kW each with shunt characteristics. The substations are not staffed as they are tele-controlled by the principle of synchronized selector automatic telephony and transmission by means of harmonic-frequency currents. The transformers are so equipped to be placed on wagons directly for transport purposes.	Two are rectifier 2 000 kW each, staffed and ren controlled with ect current tr mission and c selector system.

FRANCE alenciennes-Thionville	BAS-CONGO TO KATANGA (C.F.B.C.K.)	HUNGARY	GERMANY (D.B.)	SWITZERLAND (S.B.B.)	SWITZERLAND (B.L.S.)
	A.C. 50 CYCLES			A.C. 16.66 CYCLES	
substations are ipped with a tt group of 2 isformers of 00 kVA; and a asic » transfor- as a reserve. substations will be staffed but -controlled with ystem of coded ulses with trans- sion by means harmonic fre- ncy currents.	Substation with Scott group.	Simple single-phase transformer substations.	Substations with transformers of 6 500 kVA or rectifiers of 3 000 kW The substations are staffed with the exception of the Hamburg urban railway where the rectifiers are telecontrolled from a single control cabin	Substations equipped with 2 or 6 transformers of continuous power of 3 000 kVA and instantaneous power of 5 000 kVA each. The substations are semi-automatic. They are staffed only for maintenance. One substation only is remote controlled from another substation.	Substations with automatic track feeder circuit breakers, compressed air operated, remote controlled which are closed automatically for non-permanent short-circuits. The substations are : 1. staffed 2. remote-controlled. The section posts are controlled by hand by station personnel.

QUESTION	ALGERIA	BELGIUM (S.N.C.B.)
Appendix No. 17	**3 000 V D.C.**	
27. (a) *Is the converting equipment suitable for regenerative electric braking?*	There are in all four substations. Of these : (*a*) two are equipped with a rotary converter of 2 500 kW consisting of a three-phase synchronous (asynchronous starting by means of cage winding) with two D.C. generators of 1,5 kV connected in series and fitted with commutation poles together with compensation windings and a compensation winding for regenerative travel. Maintenance of these converters requires specialised staff and is more onerous than static rectifiers. (*b*) two are equipped with a mercury arc rectifier of 2 000 kW not suitable for regeneration. One of these substations has also a rheostat for the absorption of regenerated currents. —	It is not foreseen.
(b) *Is it used for this purpose?*	Yes, where the equipment is foreseen.	—
Appendix No. 18		
28. (a) *Are filter circuits installed?*	No information.	None have been installed up to no but their installation is foreseen in few substations.
(b) *What benefit has been derived from them?*	—	—
Appendix No. 19		
29. *Give actual total cost of substation equipment, adjusted to January 1, 1953 price levels for the actual section of electrified line.*	No information.	Substations with three arc-rectifie
(a) *excluding cost of building work.*		(a) 2 062 500
(b) *including cost of building work.*		(b) 2 392 500

ITALY (F.S.)	MOROCCO	SPAIN	
		Ujo-Busdongo	Leon-Ponferrada
	3 000	V D.C.	
es, with the addition of a w networks.	Yes, in the synchronous-generator substations.	Yes	Only one suitable arc rectifier exists at La Granja with a capacity of 800 A.
o, because they do not esent a noticeable interest.	Yes	Yes	Yes
es, « non-periodical » fil-rs.	Yes, in the mercury arc rectifier substations.	Not necessary.	Yes, they are projected.
osorption of the harmonics d security.	To avoid disturbances to the telephonic reception.	—	Unknown for the present.
bstations with two rotary insformer-rectifiers 130 kV/ 200 V with continuous load 2 000 kW.			
) staffed : 1 233 000 tele-contr.: 1 096 000) staffed : 1 370 000 tele-contr.: 1 219 300	(a) 1 519 000 (b) 1 953 000	(a) 918 000 (b) 1 020 000	(a) 510 000 (b) 612 000

QUESTION	SPAIN	NETHERLANDS	FRANCE	
	Madrid-Segovia		Paris-Lyon	Paris-Le Mans
Appendix No. 17 *(contin.)*		1 500 V D.C.		
27. (a) *Is the converting equipment suitable for regenerative electric braking?*	Yes, regeneration is simple and direct.	No	No	No
(b) *Is it used for this purpose?*	Yes	—	No	No
Appendix No. 18 *(contin.)*				
28. (a) *Are filter circuits installed?*	No, they are unnecessary.	No	No	No
(b) *What benefit has been derived from them?*	—	—	—	—
Appendix No. 19 *(contin.)*				
29. *Give actual total cost of substation equipment, adjusted to January 1, 1953 price levels for the actual section of electrified line used in question C. 24 above* :		Substations with two rectifiers :		
(a) *excluding cost of building work;*	(a) 765 000	(a) 604 950	(a) 2 905 630	(a) 2 170 000
(b) *including cost of building work.*	(b) 938 400	(b) 692 150	(b) 3 059 700	(b) 2 479 225
		The feeder lines connecting the substations to the overhead supply system and the remote control apparatus are included in the price.	It is not, however indicated to which type of substation these prices refer.	

FRANCE Valenciennes-Thionville	BAS-CONGO TO KATANGA (C.F.B.C.K.)	HUNGARY	GERMANY (D.B.)	SWITZERLAND (S.B.B.)	SWITZERLAND (B.L.S.)
	A.C. 50 CYCLES			**A.C. 16.66 CYCLES**	
Yes	Regeneration is not carried out.	Yes	No	Yes	—
—	—	Yes	No	Yes, but not always	—
No —	No —	No —	Only on the Wisental railway. Eliminate the superior harmonics generated by the commutator.	No, because they are unnecessary. —	None —
(a) 965 650 (b) 1 009 050 For substations with two intakes at 60 kV with circuit breakers 1 Scott transformer group 60/25 and 1 reserve element. Tele-controlled.	(a) 1 650 000 (b) 1 691 250	No information	(i) Substations with 2 transformers of 10 000 kVA, 4 derivations, 1 983 000. (ii) substations with 3 transformers 2 577 900 (iii) substations with 4 transformers 3 271 950 (iv) substations with 3 power commutators 61 473	(a) 1 300 000 (b) 1 650 000	(a) 250 000 (b) 350 000

1 500 V D.C. ELECTR

Availability	Wheel arrangement	Railways	Type	Year of construction	Kind of service	No in service	Average yearly running (km)	Total weight (tons)	Adhesive weight (tons)		Maximum rail tractive effort (kg)	Factor of adhesion	Maximum drawbar tractive effort (kg)
									total	per axle			
—	BoBo	S.N.C.F.	9001-9002	1953	pass.	1	—	80	80	20	—	—	15 45
—	BoBo	S.N.C.F.	9003	1952	pass.	1	—	80	80	20	16 700	1/4.76	16 45
—	BoBo	S.N.C.F.	9004	1953	pass.	1	—	80	80	20	13 800	1/5.8	13 60
92.66 %	BoBo	S.N.C.F.	8101	1949	mixed	136	120 000	80	80	20	19 900	1/4	19 60
								ball. 92	ball. 92	ball. 23		ball. 1/4.6	
82 %	BoBo	N.V.N.S. Holland	—	1950-52	mixed	50	129 400	80	80	20	17 520	1/4.57	17 10
—	BoBo	S.N.C.F.	901	1936	mixed	34	100 000	80	80	20	11 200	1/7.1	11 10
82 %	1A.Bo. A1	N.V.N.S. Holland	1001	1948-49	mixed	10	111 577	100	72	18	17 200	1/4.2	17 00
92.66 %	2D2	S.N.C.F.	9100	1950	pass.	35	235 000	144	88	22	21 326	1/4.1	21 05
—	2D2	S.N.C.F.	5400	1937	pass.	22	145 000	130	80	20	14 300	1/5.6	14 20
92.66 %	CoCo	S.N.C.F.	7101	1952	pass.	43	300 000	107	107	17.8	17 300	1/6.2	17 10
82 %	CoCo	N.V.N.S. Holland	1300	1952-53	mixed	10	128 000	110	110	18.3	26 280	1/4.2	24 90
82 %	CoCo	N.V.N.S. Holland	1201-1225	1951-53	mixed	25	108 000	110	110	18.3	—	—	21 75

COMOTIVES

Appendix No. 20.

ed at which max. ower developed kms per hour)			Maximum speed (km per hour)	Maximum rail power (HP)			Specific power (HP per ton)		Cost in Swiss Francs				Remarks
	one-hour rating	starting		continuous	one-hour rating	starting	one-hour rating	starting	Total (Millions)	per kg of weight	per unit of rail power		
											1-hr. rating	start-ing	
8	86	—	140	4 772	4 772	—	59.65	—	—	—	—	—	The details in the table do not correspond to the characteristics.
9	77	—	140	4 255	4 752	—	59.40	—	—	—	—	—	—
4	90	—	140	4 127	4 594	—	57.42	—	—	—	—	—	—
3	43	—	105	2 788	3 178	—	39.72 34.54 ball.	—	1.302	16.27	410	—	The one-hour rating tractive effort in the table does not correspond to the characteristics.
–	—	—	—	—	—	—			—	—	—		
–	71	46.5	135	—	2 800	3 000	35	51.2	0.7303	9.13	261	243	The starting power is limited to 46.5 km/p. hour for reasons of adhesion.
8	48	—	95	1 784	1 980	—	24.75	—	1.128	14.10	570	—	—
–	102	—	160	—	4 366	—	43.66	—	0.9374	9.37	215	—	As not specified, it is supposed that the characteristics given are valid for 1 350 V. The maximum effort can be sustained only up to 36.5 km p. hour for reasons of adhesion
0	68	—	150	4 750	5 371	—	37.3	—	2.127	14.77	396	—	The details in the table do not correspond to the characteristics.
0	76.5	—	130	3 639	4 050	—	31.1	—	1.975	15.19	488	—	—
8	78	—	150	4 600	5 000	—	43	—	1.573	14.30	342	—	—
–	71	36	135	—	4 200	—	38.2	56.2	1.0028	9.12	239	162	The starting power is lower than that of the one-hour rating because adhesion limits its use to 36 km p. hour.
–	—	—	—	—	—	—	—	—	—	—	—	—	The tractive effort characteristic is missing, therefore power, etc. cannot be shewn.

1 500 V D.C. ELEC

Availability	Wheel arrangement	Railways	Type	Year of construction	No. in service	Average yearly running (km)	Total weight (tons)	Adhesive weight (	
								total	per a
85 %	2(Bo2+2Bo)	N.V.N.S. Holland	—	1942-46	10	—	97	53.6	13.1 an
85 %	BoBo+22+22+BoBo	N.V.N.S. Holland	—	1938	25	—	192	105.8	13.1 an 13.6 an
—	BoBo + 22	S.N.C.F.	Z	1953	54	—	117	67	16.75
—	BoBo	S.N.C.F.	Z3801	1938	5	95 000	48.5	48.5	12.1
85 %	Bo2Bo + Bo2Bo	N.V.N.S. Holland	—	1948-51	64	212 000	169	109.2	13.4 an 13.5 13.7
85 %	Bo2Bo	N.V.N.S. Holland	—	1935	6	—	75	51.2	12.8
85 %	Bo2Bo	N.V.N.S. Holland	—	1938	5	—	81	53.2	13.2 and
85 %	Bo2Bo	N.V.N.S. Holland	—	1948-52	79	133 334	89	57.2	14.3
85 %	Bo22Bo	N.V.N.S. Holland	—	1938	19	—	106	53.2	13.2 and
85 %	Bo22Bo	N.V.N.S. Holland	—	1938	13	—	106	52.2	12.7 and
85 %	Bo22Bo + Bo2Bo	N.V.N.S. Holland	—	1942	19	—	214	107.4	13.4 and 13.6 an
—	BoBoBo	S.N.C.F.	Z3701	1938	20	110 000	95	95	15.8

TORCOACHES

Appendix No. 21.

aximum speed n per h)	Maximum rail power (HP)			Specific power HP per (ton)		Cost in Swiss Francs			
	contin-uous	one-hour rating	starting	one-hour rating	starting	Total (Millions)	per kg of weight	per unit of rail power	
								1-h rating	starting
125	—	1 069	—	11.00	—	—	—	—	—
140	—	2 138	—	11.13	—	—	—	—	—
80	—	1 760	—	26.3 (Motorcoach only) 15.0 (Whole train)	—	1.703	14.55	968	
130	—	817	—	16.84	—	1.128	23.26	1 381	
140	—	2 138	—	12.65	—	0.1068	0.632	49.96	
140	—	1 069	—	14.25	—	—	—	—	—
140	—	1 069	—	13.20	—	—	—	—	—
140	—	1 069	—	12.01	—	0.0567	0.637	53.04	
125	—	1 069	—	10.10	—	—	—	—	—
125	—	1 069	—	10.10	—	—	—	—	—
140	—	2 138	—	10.00	—	—	—	—	—
130	—	1 544	—	16.25	—	1.378	14.50	892	

3 000 V D.C. EL

Availability	Wheel arrangement	Network	Type	Year of construction	Kind of service	No in service	Average yearly running (km)	Total weight (tons)	Adhesive weight (tons)		Maximum rail tractive effort (kg)	Factor of adhesion
									Total	per axle		
96 %	BoBo	S.N.C.B.	121	1949-50	mixed	3	84 500	80	80	20	—	—
96 %	BoBo	S.N.C.B.	120	1949-50	mixed	3	84 500	80	80	20	—	—
—	BoBo	S.N.C.B.	122	in constr.	mixed	50	—	80	80	20	—	—
96 %	BoBo	S.N.C.B.	101	1949-50	mixed	20	84 500	80	80	20	—	—
—	BoBo	C.F.M. (Morocco)	—	1950	freight	9	58 200	88	88	22	17 200	1/5
—	BoBo	C.F.M. (Morocco)	—	1950	pass.	5	58 200	82	82	20.5	11 720	1/7.4
88 %	BoBo	F.S.	424	1942	mixed	158	100 000	72.4	72.4	18.1	20 000	1/3.6
88 %	2BoBo2	F.S.	428	1937	mixed	242	100 000	135	78	19.5	26 000	1/3
80 %	CoCo	RENFE	7701	1953	mixed	25	108 800	120	120	20	17 545	1/7
85 %	CoCo	RENFE	6101	1923	pass.	6	77 500	75	75	12.50	12 600	1/6
85 %	CoCo	RENFE	6001	1923	mixed	6	77 500	79.5	79.5	13.25	12 600	1/6.3
88 %	BoBoBo	F.S.	636	1939	mixed	114	100 000	101	101	16.83	26 000	1/3.9

MOTIVES

Appendix No. 22.

ed at which max. wer developed km per hour)			Maximum speed (km per hour)	Maximum rail power (HP)			Specific power (HP per ton)		Cost in Swiss Francs			
	one-hour rating	starting		continuous	one-hour rating	starting	one-hour rating	starting	total (Millions)	per kg of weight	per unit of rail power	
											1-h rating	start-ing
-	—	—	140	—	2 850	—	35.62	—	0.7316	9.14	257	—
-	—	—	140	—	2 640	—	33	—	0.7316	9.14	277	—
-	—	—	140	—	2 500	—	31.2	—	0.7316	9.14	293	—
-	—	—	140	—	2 176	—	27.2	—	0.7316	9.14	336	—
4	32	—	80	—	2 040	—	23.2	—	0.9034	10.26	443	—
8	47	—	105	—	2 040	—	24.9	—	0.9034	11.02	443	—
6	54	—	130	1 763 (f.f.) 1 867 (35 % r.f.)	2 000 (f.f.)	—	27.6	33.7	0.6197	8.56	310	253
3	71	—	130	3 190	3 550	—	26.3	—	1.1556	8.56	325	—
58	55.4	—	110	3 000	3 600	—	30	—	0.5992	4.993	166	—
9	36	—	60	1 300	1 680	—	22.4	—	0.3060	4.08	182	—
4	34	—	60	1 544	1 587	—	20	—	0.3060	3.84	193	—
5	72	—	130	2 639 r.f. 80 %	2 934 r.f. 80 %	—	29.05	—	0.8646	8.56	295	—

3 000 V D.C. ELE

Availability	Wheel arrangement	Network	Type	Year of construction	No in service	Average yearly running (km)	Total weight (tons)	Adhesive weight (tons)		Maximum rail tractive effort (kg)
								total	per axle	
—	A1.1A + A1.1A	S.N.C.B.	—	1950	25	139 500	93	—	—	—
80 %	BoBo + 2.2 + BoBo	F.S.	883	1939	16	150 000	172	126	15.75	16 000
80 %	BoBo + 2.2	F.S.	840	1948	68	150 000	100	56	14	7 500
—	BoBo	R.E.N.F.E.	—	1954	—	—	83	83	20.7	—
80 %	Bo.2.Bo + Bo.2.2.Bo + Bo.2.Bo	F.S.	ETR 300	1953	2	—	328	196.4	from 15.5 to 17	13 000
80 %	Bo.1Ao.-Ao1.Bo	F.S.	ETR 200	1935	16	—	125.5	93.1	from 15.5 to 16.3	6 500

ORCOACHES

Appendix No. 23.

eed at which max. ower developed (km per hour)			Maximum speed (km per hour)	Maximum rail power (HP)			Specific power (HP per ton)		Cost in Swiss Francs				Remarks
continuous	one-hour rating	starting		continuous	one-hour rating	starting	one-hour rating	starting	Total (Millions)	per kg of weight	per unit of rail power		
											1-h rating	starting	
—	—	—	—	—	980	—	10.5	—	0.8742	9.40	892	—	No information is available of the other types of electric motorcoaches (154 units) in service.
66	61	—	110	1 368	1 800	—	10.5	—	1.4723	8.56	818	—	The weights are given with normal load.
81	70	—	135	720	907	—	9.07	—	0.8560	8.56	944	—	
—	—	—	110	1 040	1 225	—	14.7	—	0.4391	5.291	358	—	
25	105	—	180	2 199	2 917	—	8.9	—	—	—	—	—	
90	98	—	180	1 060	1 400	—	11.1	—	1.0743	8.56	767	—	

16.66-CYCLE SINGLE-PH

Availability	Wheel arrangement	Network	Type	Year of construction	Kind of service	No in service	Average yearly running (km)	Total weight (tons)	Adhesive weight (tons)		Maximum rail tractive effort (kg)	Factor of adhesion
									Total	per axle		
90 %	BoBo	B.L.S.	Ae4/4	1944-52	pass.	6	170 000	80	80	20.00	22 000	1/3.6
88 %	BoBo	D.R.	E 10	1953	mixed	5	192 600	81	81	20.25	27 000	1/3
89,7 %	BoBo	D.R.	E 44	1932-53	mixed	118	97 446	78	78	19.50	20 000	1/3.9
93 %	BoBo	S.B.B. C.F.F. F.F.S.	Re4/4 427- 450	1946-51	mixed	50	170 000	58	58	14.50	14 000	1/4.14
93 %	BoBo	S.B.B. C.F.F. F.F.S.	Re4/4 401- 416					56	56	14	14 000	1/4
93 %	BoBo	S.B.B. C.F.F. F.F.S.	Re4/4 417- 426					57	57	14.25	14 000	1/4.1
85,5 %	1-D-1	D.R.	E 19	1940	pass.	4	199 700	113	80.8	20.2	22 400	1/3.6
85,5 %	1-D-1	D.R.	E 18	1935	pass.	34	199 700	108.5	78.1	19.525	21 000	1/3.7
—	CoCo	D.R.	E 50	1953	freight	under cons.	—	129	129	21.5	46 000	1/2.8
93 %	CoCo	S.B.B. C.F.F. F.F.S.	Ae6/6	1952-53	mixed	2	250 000	123	123	20.50	33 000	1/3.7
88 %	CoCo	D.R.	E 94	1940-53	freight	77	121 000	118.5	118.5	19.75	37 000	1/3.2
85 %	1.C.C.1	B.L.S.	Ae6/8	1926-43	mixed	8	170 000	142	120	20	36 000	1/3.3

. ELECTRIC LOCOMOTIVES

Appendix No. 24.

ed at which max. power developed (km per hour)			Maximum speed (km per hour)	Maximum rail power (HP)			Specific power (HP per ton)		Cost in Swiss Francs				Remarks
	one-hour rating	starting		continuous	one-hour rating	starting	one-hour rating	starting	Total (Millions)	per kg of weight	per unit of rail power		
											one-hour rating	starting	
—	—	—	125	—	5 000	—	62.5	—	1.0000	12.50	200	—	It is assumed that the maximum tractive effort given in the reply is the rail tractive effort.
—	83	—	130	—	4 920	—	60.7	—	0.8923	11.02	181	—	Estimated availability : as not specified, it is assumed that the maximum tractive effort given in the reply is the rail tractive effort.
0	80	76	90	2 557	3 000	3 264	38.5	41.8	0.7248	9.29	242	222	
—	—	—		—	2 400	—	41.38	—	0.840	14.50	350	—	—
—	—	—	125	—	2 300	—	41.1	—	0.840	15.00	365	—	—
—	—	—		—	2 300	—	40.3	—	0.840	14.70	365	—	—
30	180	161	180	5 000	5 440	7 900	48.1	69.9	1.055	9.34	194	133	Availability estimated to be equal to that of the E. 18.
29	124	118	150	3 920	4 220	4 800	38.9	44.2	1.013	9.34	240	211	—
—	—	63.5	100	—	—	6 585	—	—	—	—	—	—	—
—	—	—	125	—	6 000	—	48.78	—	1.620	13.17	270	—	—
30	74,5	61	90	4 200	4 400	5 331	37.1	45	1.1016	9.30	250	207	—
—	—	—	90	—	—	—	—	—	1.300	9.15	—	—	—

16.66-CYCLE SINGLE-

Availability	Wheel arrangement	Network	Type	Year of construction	No in service	Average yearly running (km)	Total weight (tons)	Adhesive weight (tons)		Maximum rail tractive effort (kg)
								Total	per axle	
—	Bo.2 + 2.2 + 2Bo	D.R.	ET 30	under cons.	—	—	140	66	16.50	14 100
86.1 %	Bo2 + 2.2 + 2Bo	D.R.	ET 32	1936	2	196 900	114	55	13.75	7 740
85.5 %	Bo.2 + 2.Bo	D.R.	ET 11	1935-1937	3	144 000	113.5	68	17	6 000
82.2 %	Bo2 + 2Bo	D.R.	ET 25	1935-1938	19	107 100	94.8	57.4	14.35	8 000
85 %	A1.2.2.1A	B.L.S.	BCFe 2/8	1935-1938	4	120 000	62	22	11	3 000
85 %	BoBo	B.L.S.	Ce 4/4	1953	2	120 000	60	60	15	12 000
85.5 %	BoBo	D.R.	ET 171	1938-1944	43	142 000	48.3	48.3	12.075	8 500
93 %	BoBo	S.B.B. C.F.F. F.F.S.	CFe 4/4	1952-1954	31	150 000	55	55	13.75	—
85.5 %	BoBo	D.R.	ET 65	1935-1938	23	126 360	63.3	63.3	15.825	12 700
85 %	Bo2Bo	B.L.S.	BCF2e 4/6	1938	3	120 000	76	54	13.5	6 000
85 %	Bo2.2.Bo	B.L.S.	BCFe 4/8	1945	3	120 000	82	52	13	6 000

- ELECTRIC MOTORCOACHES —

Appendix No. 25.

ed at which max. ower developed km per hour)			Maximum speed (km per hour)	Maximum rail power (HP)			Specific power (HP per ton)		Cost in Swiss Francs				Remarks
	one-hour rating	starting		continuous	one-hour rating	starting	one-hour rating	starting	Total (Millions)	per kg of weight	per unit of rail power		
											1-h rating	start-ing	
-	120	—	120	—	2 713	—	19.4	—	1.259	8.99	464	—	—
-	93	83	120	—	1 481	1 630	13	14.2	1.126	9.87	760	695	The weight shewn in the table does not coincide with that in diagrams Eb 3041 and Eb 3042.
0	148	104	160	1 320	1 430	1 890	12.6	16.6	1.146	10.10	801	606	Estimated availability.
8	90	66	120	1 176	1 265	1 666	13.34	17.6	0.709	7.48	560	425	—
-	—	—	110	—	500	—	8.06	—	—	—	—	—	—
-	—	—	110	—	2 000	—	33.3	—	0.800	13.33	400	—	—
-	33.5	30	80	—	1 824	2 110	37.76	43.68	0.965	19.98	529	457	Estimated availability.
-	—	—	100	—	1 500	—	27.27	—	0.730	13.27	487	—	—
9	54	39	75	1 160	1 300	1 740	20.5	27.5	0.449	7.09	345	258	Estimated availability.
-	—	—	110	—	1 000	—	13.16	—	—	—	—	—	—
-	—	—	110	—	1 000	—	12.19	—	1.000	12.2	—	1 000	—

50-CYCLE SINGLE-PHASE A.C. ELEC

Availability	Wheel arrangement	Network	Type	Year of construction	Kind of service	No in service	Average yearly running (km)	Total weight (tons)	Adhesive weight (tons)		Maximum rail tractive effort (kg)	Factor of adhesion
									Total	per axle		
—	BoCo	Hungary	—	1948	mixed	—	—	90	90	18	24 200	1/3.7
—	BoBo	S.N.C.F.	under cons.	—	mixed	—	—	83	83	20.75	18 500	1/4.5
—	BoBo	S.N.C.F.	under cons.	—	mixed	—	—	80	80	20	13 600	1/5.9
—	BoBo	Congo-Katanga	—	1953	mixed	8	—	74	74	18.5	16 000	1/4.6
89 %	CoCo	S.N.C.F.	6051	1950	mixed	1	—	104	104	17.33	17 600	1/6
—	CoCo	S.N.C.F.	under cons.	—	freight	—	—	120	120	20	28 200	1/4.25
78 %	CoCo	S.N.C.F.	6052	1951	mixed	1	—	118	118	19.7	17 700	1/6.7
—	CoCo	S.N.C.F.	under cons.	—	freight	—	—	120	120	20	24 900	1/4.8
—	BoBoBo	S.N.C.F.	6053	1953	mixed	1	—	114	114	19	18 200	1/6.3
				ELECTRIC MOTORCOACHES								
79 %	BoBo	S.N.C.F.	9051	1951	—	1	140 000	70	70	17.5	—	—

OMOTIVES AND MOTORCOACHES

Appendix No. 26.

	d at which max. wer developed m per hour)		Maximum speed (km per hour)	Maximum rail power (HP)			Specific power (HP per ton)		Cost in Swiss Francs				Remarks
	one-hour rating	starting		continuous	one-hour rating	starting	one-hour rating	starting	Total (Millions)	per kg of weight	per unit of rail power 1-h rating	per unit of rail power starting	
	50	75	125	—	4 800	4 800	53.33	53.33	—	—	—	—	With phase and frequency converter.
	65	—	120	3 730	4 100	—	49.4	—	1.068	12.87	260	—	5 ignitron units under construction.
	61	—	105	—	2 750	—	34.37	—	1.046	13.07	380	—	15 single-phase, commutator type motor units under construction.
-	—	—	70	—	1 800	—	—	—	—	—	—	—	An availability of 30 % is indicated : technical details and cost are missing.
	69	—	100	4 300	4 470	—	43	—	—	—	—	—	Direct motors.
	49	—	60	3 740	4 200	—	35	—	1.473	12.27	351	—	20 single-phase/three-phase units under construction.
-	65	—	100	3 722	4 100	—	34.7	—	—	—	—	—	Double single-phase commutator type motors.
5	32.5	—	60	2 400	2 400	—	20	—	1.308	10.90	545	—	65 single-phase/direct current units with rotary converter under construction.
	57	—	100	3 190	3 547	—	31.1	—	—	—	—	—	800 volt direct current motors with rotary converter.
					ELECTRIC MOTORCOACHES								
-	—	—	80	—	1 700	—	24.3	—	1.703	24.32	100	—	Single-phase, commutator type motors : characteristics do not correspond with the details in the table as it has greater power than that shewn.

Appendix No 27.

TYPES OF MOTIVE POWER UNITS UNDER EXAMINATION.

A) Locomotives.

Wheel arrangement	*Direct Current System*		*Alternating Current System*		*Totals*
	1 500 V	3 000 V	16.66 c.	50 c.	
BoBo	6	7	6	3	22
1 D 1	—	—	2	—	2
1 A Bo A 1	1	—	—	—	1
2 D 2	2	—	—	—	2
2 BoBo 2	—	1	—	—	1
BoCo	—	—	—	1	1
CoCo	3	3	3	4	13
BoBoBo	—	1	—	1	2
1 CC 1	—	—	1	—	1
	12	12	12	9	45

B) Motorcoaches.

Wheel arrangement	1 500 V	3 000 V	16.66 c.	50 c.	*Totals*
Bo 2	1	—	4	—	5
A 1 1 A	—	1	—	—	1
A1.2 2.1A	—	—	1	—	1
BoBo	3	3	4	1	11
Bo 2 Bo	4 } + 1	1	1	—	2 { 5
Bo.2.2.Bo.	2 }		1		3
BoBoBo	1	—	—	—	1
Bo 1 AoAo 1 Bo . . .	—	1	—	—	1
	12	6	11	1	30
Grand Totals	24	18	23	10	75

Appendix No. 28.

COMPARISON FOR 1 500 V D.C. LOCOMOTIVES

	Percentage value in respect of the locomotive to which the highest value applies.	
1) loco with max. power 1-h rating : 2D2 type 9100 S.N.C.F. : 5 370 HP.	5 370/5 440	= 98.71 %
2) loco with max. relation $\frac{\text{power 1-h rating}}{\text{power continuous}}$: BoBo type 8101, S.N.C.F.	1.1399/1.2923	= 88.21 %
3) loco with max. relation $\frac{\text{power starting}}{\text{power 1-h rating}}$: No details available.		
4) loco with max. spec; power, 1-h rating : BoBo, type 9000 S.N.C.F. : 59.65 HP per ton	59.65/62.5	= 95.44 %
5) loco with max. speed : 1A.Bo A1, type 1001, N.V.N.S. : 160 km p. h	160/180	= 88.89 %
6) loco with max. rail tractive effort : CoCo Type 1300, N.V.N.S. : 26 300 kg	26300/46000	= 57.17 %
7) loco with max. use of adhesion : 2D2 type 9100, S.N.C.F. : 1/4, 1 = 0.244.	0.244/0.357	= 68.35 %
8) loco with min. weight par axle : CoCo type 7101, S.N.C.F. : 17.8 tons	17.8/11	= 161.82 %
9) loco with max. relation $\frac{\text{power 1-h rating}}{\text{Weight per axle}}$: CoCo type 7101, S.N.C.F. : 281 HP per ton	281/293	= 95.90 %
10) loco with max. power 1-h rating per axle : 2D2 type 9100, S.N.C.F. : 1 343 HP	1 343/1 360	= 98.75 %
11) loco with min. cost per unit of power 1-h rating : 1A. Bo. A1 type 1001, N.V.N.S. : 215 Swiss fr. per HP	215/166	= 129.52 %

Appendix No. 29.

COMPARISON BETWEEN 1 500 V D.C. ELECTRIC MOTORCOACHES

	Percentage value in respect of the motorcoach to which the highest value applies.	
1) motorcoach with max. power 1-h rating : BoBo + 22 + 22 + BoBo Bo 2 Bo + Bo 2 Bo Bo 2 2 Bo + Bo 2 Bo N.V.N.S. (Holland) 2 138 HP.	$\frac{2\,138}{2\,713}$	= 78.80 %
2) m. coach with max. relation $\frac{\text{power 1-h rating}}{\text{power continuous}}$:	No details available.	
3) m. coach with max. relation $\frac{\text{power starting}}{\text{power 1-h rating}}$:	No details available.	
4) m. coach with max. spec. power 1-h rating : (referring to whole train) BoBo, type z 3801 S.N.C.F. : 16.84 HP p. ton	$\frac{16.84}{37.76}$	= 44.60 %
5) m. coach with max. speed : BoBo + 22 + 22 + BoBo Bo 2 Bo + Bo 2 Bo + Bo 2 Bo + Bo 22 Bo Bo 2 Bo Holland 140 km per h	$\frac{140}{180}$	= 77.78 %
6) m. coach with min. weight per axle : BoBo type z 3801 S.N.C.F. : 12.1 tons per axle	$\frac{12.1}{11}$	= 110 %

Appendix No. 30.

COMPARISON FOR 3 000 V D.C. LOCOMOTIVES

	Percentage value in respect of the locomotive to which the highest value applies.
1) loco with max. power 1-h rating : 2 BoBo 2, type E 428, F.S. : 3550 HP	3 550/5 440 = 65.26 %
2) loco with max. relation $\frac{\text{power 1-h rating}}{\text{power continuous}}$: CoCo, type 6101, R.E.N.F.E. : 1.2923	100 %
3) loco with max. relation $\frac{\text{power starting}}{\text{power 1-h rating}}$:	No details available.
4) loco with max. spec. power, 1-h rating : BoBo, type 121, S.N.C.B. : 35.62 HP p. ton	35.62/62.5 = 56.99 %
5) loco with max. speed : BoBo, type 121/120/122/101 S.N.C.B. : 140 km p.h.	140/180 = 77.78 %
6) loco with max. rail tractive effort : BoBoBo, type E 636, F.S. : 26 300 kg	26 300/46 000 = 57.17 %
7) loco with max. use of adhesion : 2 BoBo 2, type E 428 : F.S. : 1/3 = 0.333	0.333/0.357 = 93.28 %
8) loco with min. weight per axle : CoCo, type 6101, R.E.N.F.E. : 12.50 tons	12.50/11 = 113.64 %
9) loco with max. relation $\frac{\text{power 1-h rating}}{\text{weight per axle}}$: 2 BoBo 2, type E 428, F.S. : 182 HP per ton	182/293 = 62.12 %
10) loco with max. power 1-hr. rating per axle : 2 BoBo 2, type E 428, F.S. : 887 HP.	887/1 360 = 65.22 %
11) loco with min. cost per unit of power 1-h rating : CoCo, type 7701, R.E.N.F.E. : 166 Swiss francs per HP	= 100 %

Appendix No. 31.

COMPARISON BETWEEN 3 000 V D.C. ELECTRIC MOTORCOACHES

	Percentage value in respect of the motorcoach to which the highest value applies.
1) motorcoach with max. power 1-h rating : Bo 2 Bo + Bo 22 Bo + Bo 2 Bo type ETR 300 F.S. : 2 199 HP.	$\frac{2\,199}{2\,713}$ = 81.05 %
2) motorcoach with max. relation $\frac{\text{power 1-h rating}}{\text{power continuous}}$ BoBo + 22, type 840 F.S. : 1.26	100 %
3) motorcoach with max. relation $\frac{\text{power starting}}{\text{power 1-h rating}}$:	No details available.
4) motorcoach with max. spec. power 1-h rating : (referring to whole train) BoBo, R.E.N.F.E. : 14.7 HP per ton	$\frac{14.7}{37.76}$ = 38.93 %
5) motorcoach with max. speed : Bo 2 Bo + Bo 22 Bo + Bo 2 Bo, type ETR 300 — Bo 1Ao Ao 1 Bo type ETR 200 F.S. : 180 km p.h.	100 %
6) motorcoach with min. weight par axle : BoBo + 22 type 840 F.S. : 14 tons per axle	$\frac{14}{11}$ 127.27 %

Appendix No. 32.

COMPARISON FOR 16.66—CYCLE A.C. LOCOMOTIVES

Percentage value in respect of the locomotive to which the highest value applies.

1) loco with max. power 1-h rating :
1 D 1, E 19 D.B. : 5 440 HP . . . . 100 %

2) loco with max. relation $\frac{\text{power 1-h rating}}{\text{power continuous}}$
BoBo, E 44, D.B. : 1.1732 . . . . 1.1732/1.2923 = 90.78 %

3) loco with max. relation $\frac{\text{power starting}}{\text{power 1-h rating}}$
1 D 1, E 19, D.B. : 1.45 . . . . = 100 %

4) loco with max. spec. power, 1-h rating :
BoBo, Ae 4/4 B.L.S. : 62.5 HP per ton . . . . = 100 %

5) loco with max. speed :
1 D 1, E 19, D.B. : 180 km p.h = 100 %

6) loco with max. rail tractive effort :
CoCo Re 4/4 S.B.B. C.F.F. F.F.S. : 46 000 kg. . . . . = 100 %

7) loco with max. use of adhesion :
CoCo, E 50, D.B. : 1/2.8 = 0.357 . . . . = 100 %

8) loco with min. weight per axle :
CoCo 401 Rh. B. : 11 tons . . . . = 100 %

9) loco with max. relation $\frac{\text{power 1-h rating}}{\text{weight per axle}}$
CoCo Ae 6/6 S.B.B. C.F.F. F.F.S. : 293 HP p. ton . . . . . . = 100 %

10) loco with max. power, 1-h rating per axle :
1 D 1, E 19, D.B. : 1 360 HP . . . . = 100 %

11) loco with min. cost per unit of power 1-h rating :
BoBo, E 10, D.B. : 181 Swiss francs per HP . . . . 181/166 = 109.04 %

Appendix No. 33.

COMPARISON BETWEEN THE SINGLE-PHASE, 16 2/3 rds AND 50 CYCLE, A.C. ELECTRIC MOTORCOACHES

Percentage value in respect of the motorcoach to which the highest value applies.

1) motorcoach with max. power 1-h rating :

Bo 2 + 22 + 2 Bo type ET 30 of D.B. : 2 713 HP. . . . . . = 100 %

2) motorcoach with max. relation $\dfrac{\text{power 1-h rating}}{\text{power continuous}}$

BoBo, type ET 65 of D.B. : 1.12 . . . . $\dfrac{112}{126}$ = 88.89 %

3) motorcoach with max. relation $\dfrac{\text{power starting}}{\text{power 1-h rating}}$ (Only detail available).

BoBo, type ET 65 of D.B. : 1.34 . . . . = 100 %

4) motorcoach with max. spec. power, 1-h rating :
(referring to whole train)

BoBo, type ET 171 of D.B. : 37.76 HP p. ton . . . . = 100 %

5) motorcoach with max. speed :

Bo 2 + 2 Bo, type ET 11 of D.B. : 160 km per hour . . . . . $\dfrac{160}{180}$ = 88.89 %

6) motorcoach with min. weight per axle :

type A1.22.1A, type BCFe 2/8 of B.L.S. : 11 tons per axle . . . = 100 %

For the only *single-phase, 50-cycle, A.C. electric motorcoach*, the following percentage values of the 6 above mentioned parameters are available :

1° : $\dfrac{1\,700}{2\,713}$ = 62.66 %.

2° & 3° : no details available.

4° : $\dfrac{24.3}{37.76}$ = 32.92 %.

5° : $\dfrac{80}{180}$ = 44.44 %.

6° : $\dfrac{17.5}{11}$ = 159.1 %.

Appendix No. 34.

COMPARISON FOR 50—CYCLE, A.C. LOCOMOTIVES

	Percentage value in respect of the locomotive to which the highest value applies.	
1) loco with max. power 1-h rating : BoCo, single-phase/three-phase type of the Hungarian Railways : 4 800 HP	4 800/5 440	= 88.23 %
2) loco with max. relation $\frac{\text{power 1-h rating}}{\text{power continuous}}$ CoCo, single-phase/three-phase type, under constr. S.N.C.F. : 1.1230.	1.1230/1.2923	= 86.90 %
3) loco with max. relation $\frac{\text{power starting}}{\text{power 1-h rating}}$	No details available.	
4) loco with max. spec. power, 1-h rating : BoCo, single-phase/three-phase type of the Hungarian Railways : 53.33 HP p. ton	53.33/62.5	= 85.33 %
5) loco with max. speed : BoCo, single-phase/three-phase type, of the Hungarian Railways : 125 km p.h	125/180	= 69.44 %
6) loco with max. rail tractive effort : CoCo, single-phase/three-phase type, under constr. S.N.C.F. 28 200 kg	28 200/46 000	= 61.30 %
7) loco with max. use of adhesion : BoCo, single-phase/three-phase type of the Hungarian Railways: 1/3.7	0.270/0.357	= 75.63 %
8) loco with min. weight per axle : CoCo, single-phase, commutator type motors, S.N.C.F. : 17.33 tons.	17.33/11	= 157.54 %
9) loco with max. relation $\frac{\text{power 1-h rating}}{\text{weight per axle}}$ BoCo, single-phase/three-phase type of the Hungarian Railways : 267 HP per ton	267/293	= 91.13 %
10) loco with max. power, 1-h rating per axle : BoBo ignitron, under constr. S.N.C.F. : 1025 HP	1025/1360	= 75.37 %
11) loco with min. cost per unit of power 1-h rating : BoBo ignitron, under constr. S.N.C.F. : 260 Swiss francs per HP	260/166	= 156.63 %

Appendix No. 35.

COLLECTION OF THE COMPARATIVE DETAILS BETWEEN THE TRACTIVE UNITS OF THE DIFFERENT SYSTEMS

A — LOCOMOTIVES

1. *Comparison of max. powers (HP).*

a) *max. continuous power* :

a_1)	1 500 V D.C. system . . .	4 750	loco 2 D 2 type 9100 of the S.N.C.F.
a_2)	3 000 V D.C. system . . .	3 190	loco 2 BoBo 2 type E 428 of the F.S.
a_3)	16.66-cycle A.C. system . .	5 000	loco 1 D 1 type E 19 of the D.B.
a_4)	50-cycle A.C. system . . .	4 300	loco CoCo type 6051 of the S.N.C.F.

b) *max. power, 1-h rating* :

b_1)	1 500 V D.C. system . . .	5 370	loco 2 D 2 type 9100 of the S.N.C.F.
b_2)	3 000 V D.C. system . . .	3 550	loco 2 BoBo 2 type E 428 of the F.S.
b_3)	16.66-cycle A.C. system . .	5 440	loco 1 D 1 type E 19 of the D.B.
b_4)	50-cycle A.C. system . . .	4 800	loco BoCo of Hungarian Railw. (no details of the continuous power are available for this type).

c) *max. starting power* :

c_1)	1 500 V D.C. system . . .	no details available.	
c_2)	3 000 V D.C.	no details available.	
c_3)	16.66-cycle A.C. system . .	7 900	loco 1 D 1 type E 19 of the D.B.
c_4)	50-cycle A.C. system . . .	4 800	loco BoCo of the Hungarian Railways (for the others, no details are available).

2. *Relation* : *1-h rating power/continuous power* (for the machines for which details of the two powers have been obtained).

a)	1 500 V D.C. system . . .	1.1399	loco BoBo type 8101 of the S.N.C.F.
b)	3 000 V D.C. system . . .	1.2923	loco CoCo type 6101 of the R.E.N.F.E.
c)	16.66-cycle A.C. system . .	1.1732	loco BoBo type E 44 of the D.B.
d)	50-cycle A.C. system . . .	1.1230	loco CoCo of the S.N.C.F. for freight traffic, under construction.

3. *Relation* : *starting power / 1-h rating power* (for the machines for which details of the two powers have been obtained).

a)	1 500 V D.C. system . . .	no details available.	
b)	3 000 V D.C. system . . .	no details available.	
c)	16.66-cycle A.C. system . .	1.4522	loco 1 D 1 type E 19 of the D.B.
d)	50-cycle A.C. system . . .	1.0000	loco BoCo of the Hungarian Railways (only detail obtained).

4. *Max. specific power* (HP per ton)

a) 1 500 V D.C. system :

a_1)	1-h rating power	59.65	loco BoBo — type 9000 of the S.N.C.F.
a_2)	starting power	56.2	loco CoCo — type 1300 of the N.V.N.S. (on two locomotives of which the starting power has been given).

b) 3 000 V D.C. system :

b_1)	power 1-h rating	35.62	loco BoBo — type 121 of the S.N.C.B.
b_2)	starting power	33.7	loco 2 BoBo 2 — type 428 of the F.S. (only detail obtained).

c) 16.66-cycle, A.C. system :

c_1) power 1-h rating	62.50	loco BoBo — type Ae 4/4 of the B.L.S.
c_2) starting power	69.90	loco 1 D 1 — type E 19 of the D.B. (on four locomotives of which the starting power has been given).

d) 50-cycle, A.C. system :

d_1) power 1-h rating	53.33	loco BoCo — of the Hungarian Railways.
d_2) starting power	53.33	loco BoCo — of the Hungarian Railways (only detail obtained).

5. *Minimum specific power* (HP per ton)

a) 1 500 V D.C. system :

a_1) power 1-h rating	24.75	loco BoBo — type 901 of the S.N.C.F.
a_2) starting power	51.2	loco BoBo — type 1950/52 of the N.V.N.S. (on two locomotives).

b) 3 000 V D.C. system :

b_1) power, 1-h rating	20	loco CoCo — type 6001 of the R.E.N.F.E.
b_2) starting power	no details available.	

c) 16.66-cycle, A.C. system :

c_1) power, 1-h rating	37.1	loco CoCo — type E 94 of the D.B.
c_2) starting power	41.8	loco BoBo — type E 44 of the D.B. (on four locomotives).

d) 50-cycle, A.C. system :

d_1) power, 1-h rating	20	loco CoCo — single-phase/D.C. with rotary converter of the S.N.C.F. (under construction).
d_2) starting power	no details available.	

6. *Maximum speeds* (km per hour)

a) 1 500 V D.C. system . . .	160 km per h	1 A.Bo.A 1 type 1001 of the N.V.N.S.
b) 3 000 V D.C. system . . .	140 km per h	BoBo type 121, 120, 122, 101 of S.N.C.B.
c) 16.66-cycle, A.C. system. .	180 km per h	1 D 1 type E 19 of the D.B.
d) 50-cycle, A.C. system . . .	125 km per h	BoCo of the Hungarian Railways.

7. *Max. rail tractive effort* (kg)

a) 1 500 V D.C. system . . .	26 300	loco CoCo type 1300 of the N.V.N.S.
b) 3 000 V D.C. system . . .	26 000	loco BoBoBo type E 636 and loco 2 BoBo 2 type E 428 of the F.S.
c) 16.66-cycle, A.C. system. .	46 000	loco CoCo type Re 4/4 of S.B.B., C.F.F., F.F.S.
d) 50-cycle, A.C. system . . .	28 200	loco CoCo, freight type under construction S.N.C.F.

8. *Relation* : *Max. rail tractive effort/weight per axle* :

a) 1 500 V D.C. system . . .	1/4.1	loco 2 D 2 type 9100 of the S.N.C.F.
b) 3 000 V D.C. system . . .	1/3	loco 2 BoBo 2 type E 428 of the F.S.
c) 16.66-cycle, A.C. system. .	1/2.8	loco CoCo type E 50 of the D.B.
d) 50-cycle, A.C. system . . .	1/3.7	loco BoCo of the Hungarian Railways.

9. *Weight per driving axle* (tons)

a) 1 500 V D.C. system :

a_1) max. weight per axle . . .	23	loco BoBo type 8101 of the S.N.C.F. (ball.).
a_2) min. weight per axle . . .	17.8	loco CoCo type 7101 of the S.N.C.F.

b)	3 000 V D.C. system :		
b₁)	max. weight per axle	22	loco BoBo of the C.F.M.
b₂)	min. weight per axle	12.50	loco CoCo type 6101 of the R.E.N.F.E.
c)	16.66-cycle, A.C. system :		
c₁)	max. weight per axle	21.5	loco CoCo type E 50 of the D.B.
c₂)	min. weight per axle	11	loco CoCo type 401 of the Rh.B. (this locomotive is not included in the table).
d)	50-cycle, A.C. system :		
d₁)	max. weight per axle	20.75	loco BoBo under construction by the S.N.C.F. (ignitron).
d₂)	min. weight per axle	17.33	loco CoCo type 6051 of the S.N.C.F.

10. *Relation : power/weight per axle* (HP per ton)

a)	1 500 V D.C. system :		
a₁)	continuous power	258	loco CoCo type 7101 of the S.N.C.F.
a₂)	power, 1-h rating	281	loco CoCo type 7101 of the S.N.C.F.
a₃)	starting power	no details available.	
b)	3 000 V D.C. system :		
b₁)	continuous power	163	loco 2 BoBo 2 type 428 of the F.S. (on six locomotives).
b₂)	power, 1-h rating	182	loco 2 BoBo 2 type 428 of the F.S.
b₃)	starting power	no details available.	
c)	16.66-cycle, A.C. system :		
c₁)	continuous power	247	loco 1 D 1 type E 19 of the D.B. (on four locomotives).
c₂)	power, 1-h rating	293	loco CoCo type Ae 6/6 of the S.B.B.,C.F.F.,F.F.S.
c₃)	starting power	391	loco 1 D 1 type E 19 of the D.B. (on five locomotives).
d)	50-cycle, A.C. system :		
d₁)	continuous power	248	loco CoCo type 6051 of the S.N.C.F. (on two thirds of the locomotives).
d₂)	power, 1-h rating	267	loco BoCo of the Hungarian Railways.
d₃)	starting power	no details available.	

11. *Relation : power/number of driving axles* (HP per axle)

a)	1 500 V D.C. system :		
a₁)	continuous power	1 187	loco 2 D 2 type 9100 of the S.N.C.F. (on seven locomotives).
a₂)	power, 1-h rating	1 343	loco 2 D 2 type 9100 of the S.N.C.F.
a₃)	starting power	no details available.	
b)	3 000 V D.C. system :		
b₁)	continuous power	797	loco 2 BoBo 2 type E 428 of the F.S. (on 50 % of the locomotives).
b₂)	power, 1-h rating	887	loco 2 BoBo 2 type E 428 of the F.S.
b₃)	starting power	no details available.	
c)	16.66-cycle, A.C. system :		
c₁)	continuous power	1 250	loco 1 D 1 type E 19 of the D.B. (on four locomotives).
c₂)	power, 1-h rating	1 360	loco 1 D 1 type E 19 of the D.B.
c₃)	starting power	1 975	loco 1 D 1 type E 19 of the D.B. (on five locomotives).
d)	50-cycle, A.C. system :		
d₁)	continuous power	932	loco BoBo under construction by S.N.C.F. (on two thirds of the locomotives (ignitron).
d₂)	power, 1-h rating	1 085	loco BoBo under construction by S.N.C.F. (on two thirds of the locomotives (ignitron).
d₃)	starting power	no details available.	

12. *Cost per unit of power* (Swiss francs per HP)

a)	1 500 V D.C. system :		
a_2)	power 1-h rating :		
a_{21})	max. cost	570	loco BoBo type 9004 of the S.N.C.F.
a_{22})	min. cost	215	loco 1A.Bo.A1 type 1001 of the N.V.N.S.
a_3)	starting power : (two locomotives only)		
a_{31})	max. cost	243	loco BoBo type 1950/52 of the N.V.N.S.
a_{32})	min. cost	162	loco CoCo type 1300 of the N.V.N.S.
b)	3 000 V D.C. system :		
b_2)	power, 1-h rating :		
b_{21})	max. cost	443	loco BoBo type CFM passenger and loco BoBo type CFM freight.
b_{22})	min. cost	166	loco CoCo type 7701 of the R.E.N.F.E.
b_3)	starting power	no details available.	
c)	16.66-cycle, A.C. system :		
c_2)	power, 1-h rating :		
c_{21})	max. cost	365	loco BoBo type Ae 4/4 (from 401 to 426) S.B.B.
c_{22})	min. cost	181	loco BoBo type E 10 of the D.B.
c_3)	starting power : (on four locomotives)		
c_{31})	max. cost	222	loco BoBo type E 44 of the D.B.
c_{32})	min. cost	133	loco 1 D 1 type E 19 of the D.B.
d)	50-cycle, A.C. system :		
d_2)	power, 1-h rating :		
d_{21})	max. cost	545	loco CoCo under construction (with single-phase/D.C. gr.) of the S.N.C.F.
d_{22})	min. cost	260	loco BoBo under construction (ignitron) of the S.N.C.F.
d_3)	starting power	no details available.	

LOCOMOTIVES WHICH REACH THE MAXIMUM FOR EACH OF THE PARAMETERS INDICATED

1) loco with max. power, 1-h rating : 16.66-cycle, AC, 1 D 1 E 19 D.B. 5 440 HP

2) loco with max. relation $\frac{\text{power 1-h rating}}{\text{continuous power}}$: 3 000 V DC CoCo, 6101 R.E.N.F.E. 1.2923

3) loco with max. relation $\frac{\text{starting power}}{\text{power 1-h rating}}$: 16.66-cycle, AC 1 D 1, E 19, D.B. 1.45

4) loco with max. spec. power, 1-h rating : 16.66-cycle, AC, BoBo, Ae 4/4 B.L.S. . . . . 62.5 HP per ton

5) loco with max. speed : 16.66-cycle, AC, 1 D 1, E 19, D.B. . . . . 180 km per hour

6) loco with max. rail tractive effort : 16.66-cycle, AC, CoCo Re 4/4, S.B.B.. C.F.F., F.F.S. . . . . 46 000 kg

7) loco with max. use of adhesion : 16.66-cycle, AC, CoCo, E 50, D.B. 1/2.8 = 0.357

8) loco with min. weight per axle : 16.66-cycle, AC CoCo 401 Rh. B.. . 11 tons

9) loco with max. relation $\frac{\text{power1-h rating}}{\text{weight per axle}}$: 16.66-cycle, AC, Ae 6/6 S.B.B., C.F.F., F.F.S. . . . . 293 HP per ton

10) loco with max. power, 1-h rating per axle : 16.66-cycle, AC, 1 D 1, E 19, D.B. . . . . 1 360 HP

11) loco with min. cost per unit of power, 1-h rating : 3 000 V D.C. CoCo 7701 R.E.N.F.E. . . . . 166 Sw. fr. per HP

PERCENTAGE DIFFERENCES IN RESPECT OF 100 % FOR THE VARIOUS SYSTEMS

	1 500 V	3 000 V	16.66-cycle	50-cycle
1) max. power, 1-h rating	— 1.29	— 34.74	—	— 11.77
2) max. relation $\frac{\text{power 1-h rating}}{\text{continuous power}}$	— 11.79	—	— 9.22	— 13.10
3) max. relation $\frac{\text{starting power}}{\text{power 1-h rating}}$	no details available			
4) max. spec. power 1-h rating	— 4.56	— 43.01	—	— 14.67
5) max. speed	— 11.11	— 22.22	—	— 30.56
6) max. tractive effort	— 42.83	— 42.83	—	— 38.70
7) max. use of adhesion	— 31.65	— 6.72	—	— 24.37
8) min. weight per axle	+ 61.82	+ 13.64	—	+ 57.54
9) max. relation $\frac{\text{power 1-h rating}}{\text{weight per axle}}$	— 4.10	— 37.88	—	— 8.87
10) max. power, 1-h rating per axle	— 1.25	— 34.78	—	— 24.63
11) min. cost per unit of power, 1-h rating	+ 29.52	—	+ 9.04	+ 56.63

B. — MOTORCOACHES

(for the single-phase, 50-cycle system, the details refer to the BoBo type 9051 motorcoach of the S.N.C.F., only example mentioned in the original reports from the railway networks using this system)

1) *Comparison of the max. power, 1-h rating* :

a) 1 500 V D.C. system	2 138	various types of the Dutch railways
b) 3 000 V D.C. system	2 199	ET 300 of the F.S.
c) 16.66-cycle, A.C. system . . .	2 713	ET 30 of the D.B.
d) 50-cycle, A.C. system	1 700	type 9051 of the S.N.C.F.

2) Max. relation $\frac{\text{power 1-h rating}}{\text{power, continuous}}$

a) 1 500 V D.C. system	no details available	
b) 3 000 V D.C. system	1.26	type 840 F.S.
c) 16.66-cycle, A.C. system . . .	1.12	type ET 65, D.B.
d) 50-cycle, A.C. system	no details available	

3) Max. relation $\dfrac{\text{starting power}}{\text{power, 1-h rating}}$

the only detail available is that of the BoBo, type ET 65 motorcoach of the D.B. : value of the relation 1.34

4) *Max. spec. power 1-h rating* :

a) 1 500 V D.C. system	16.84 HP per ton, BoBo, type z 3801, S.N.C.F.
b) 3 000 V D.C. system	14.70 HP per ton, BoBo, R.E.N.F.E.
c) 16.66-cycle, A.C. system . . .	37.76 HP per ton, type ET 171, D.B. (BoBo)
d) 50-cycle, A.C. system	24.32 HP per ton, BoBo, type 9051, S.N.C.F.

5) *Max. speed* :

a) 1 500 V D.C. system	140 km per hour, various wheel arrangements and types Dutch Railways.
b) 3 000 V D.C. system	180 km per hour, ETR 300 and ETR 200, F.S.
c) 16.66-cycle, A.C. system . . .	160 km per hour, ET 11, D.B.
d) 50-cycle, A.C. system	80 km per hour, 9051 S.N.C.F.

6) *Minimum weight per axle* :

a) 1 500 V D.C. system	12.1 tons per axle, BoBo, type z 3801, S.N.C.F.
b) 3 000 V D.C. system	14 tons per axle, BoBo + 22, type 840 F.S.
c) 16.66-cycle, A.C. system . . .	11 tons per axle, A1.22.1A, type BCFe 2/8 of B.L.S.
d) 50-cycle, A.C. system	17.5 tons per axle, BoBo, type 9051, S.N.C.F.

PERCENTAGE DIFFERENCES IN RESPECT OF 100 % FOR THE VARIOUS SYSTEMS

	1 500 V	3 000 V	16.66-cycle	50-cycle
1) Max. power, 1-h rating	— 21.20	— 18.95	—	— 37.34
2) Max. relation $\dfrac{\text{power 1-h rating}}{\text{continuous power}}$	no details available	—	— 11.11	no details available
3) Max. relation $\dfrac{\text{starting power}}{\text{continuous power}}$	no details available			
4) Max. spec. power, 1-h rating	— 55.40	— 61.07	—	— 67.08
5) Max. speed	— 22.22	—	— 11.11	— 55.56
6) Minimum weight per axle	— 10	+ 27.27	—	+ 59.10

Appendix No. 36.

COMPARISON OF THE COST OF THE INSTALLATIONS FOR THE VARIOUS SYSTEMS OF ELECTRIC TRACTION

1) Cost overhead supply system

(Sw. fr. per km of one track of double-track line)

1 500 V			
France	reinforced catenary	90 055	
	normal catenary	74 865	
Holland		58 860	
3 000 V			
Belgium		57 750	
Morocco		43 400	
Italy		45 240	
16.66-cycle			
Germany	open line	21 813	Let us say an average of 28 500, i.e. 20 % stations
	in stations	33 711	
Switzerland	S.B.B.	50 — 60 000	
	B.L.S.	100 000	(single track)
50-cycle			
Congo		49 500	
France		50 995	

2) Average distances between the substations

1 500 V	
France (P. — Le Mans)	20.5 km
Holland	20 km
3 000 V	
Belgium	30 km
Italy	40 km
Morocco	40 km
16.66-cycle	
Germany	50 km
50-cycle	
France	62 km
Congo	70 km

3) Cost of the substations

	per substation	per km
1 500 V		
France	2 479 225	120 938
Holland	692 150	34 607
3 000 V		
Belgium	2 392 500	79 750
Italy	1 219 300	30 482
Morocco	1 953 000	48 825
16.66-cycle		
Germany	1 983 000	39 660
50-cycle		
France	1 000 000	16 129
Congo	1 691 250	24 161

4) Total cost of installations in Sw. fr. per km of double track

1 500 V

France . . . . 90 055 × 2 + 120 938 = 301 048 max.
74 865 × 2 + 120 938 = 270 688
Holland . . . . 58 860 × 2 + 34 607 = 152 327

3 000 V

Belgium . . . . 57 750 × 2 + 79 750 = 195 250
Italy . . . . 45 240 × 2 + 30 482 = 120 962
Morocco . . . . 43 400 × 2 + 48 825 = 135 625

16.66-cycle

Germany . . . . 28 500 × 2 + 39 660 = 96 660

50-cycle

France . . . . 50 995 × 2 + 16 129 = 118 119
Congo . . . . 49 500 × 2 + 24 161 = 123 161

Economies — passage to 50 cycle :

France (min.) . . . . 270 668 — 118 119 = 152 549 $\left\{ \dfrac{152\ 549}{270\ 668} \right. = 56.36\ \%$

Belgium . . . . 195 250 — 123 161 = 72 089 $\left\{ \dfrac{72\ 089}{195\ 250} \right. = 36.92\ \%$

Appendix No. 37

ONUS OF INTEREST, REPLACEMENT AND MAINTENANCE QUOTAS FOR THE DIFFERENT SYSTEMS OF ELECTRIC TRACTION

	Belgium 3 000 V DC	*Holland* 1 500 V DC	*France* 1 500 V DC	*France* 50 c. AC	*S.B.B.* 16.66-c. AC	*B.L.S.* 16.66-c. AC
POWER STATIONS						
Interest.	—	—	—	—	4 % in 62 % of the cap. invested	—
Replacement	—	—	—	—	50 years without interest	—
Repairs & maintenance	—	—	—	—	24 % of the replacement quota	—
HIGH VOLTAGE SUPPLY LINES						
Interest.	—	(*) 4 % on av. cap. inv.	(*) 5 %	(*) 5 %	not shewn	3 %
Replacement	—	25 years all lines in cables	50 years	50 years	40 years without interest	50 years without interest
Repairs & maintenance	—	15.2 % of replacement quota	33 % of replacement quota	not shewn	71.4 % of the replacement quota	100 % of the replacement quota
SUBSTATIONS						
Interest.	5 % (18 years)	4 % on av. of cap. invested	5 %	5 %	4 % in 53.5 % of capital	3 %
Replacement	30 years	33 years build. 25 years app.	75 years build. 25 years app.	75 years build. 25 years app.	38 years without inter.	50 years without inter
Repairs & maintenance	108 % replacement quota	38.2 % replacement quota	70 % Le Mans rep. quota 32 % Lyon	100 rep. quota	62.4 % of rep. quota	136 % of rep. quota
Operating cost . . .		not shewn	not shewn	not shewn	not shewn	not shewn
CONTACT LINE						
Interest.	5 % (18 years)	4 % on av. cap. invested	5 %	5 %	4 % on 48.1 % of cap.	3 %
Replacement contact wire	60 years	12 years	50 years	50 years	40 years	50 years
replacement remaining parts		40 years				50 years
repairs & maintenance	120 % rep. quota	36.4 % rep. quota	580 % Le Mans 200 % Lyon	566 %	130 %	219 %
TRACTIVE UNITS						
Interest.	5 % (18 years)	4 %	5 %	5 %	—	3 %
Replacement	45 years		40 years	40 years	No information	33-40 years
Repairs & maintenance	222 % rep. quota	108 % rep. quota	435 % Le Mans 520 % Lyon	348 %		331 % rep. quota
Operating.	—	—	—	—	—	—

(*) These details are included for information only; as they refer to installations which would have been necessar with any system of electric traction, the corresponding costs do not come into the comparison.

Appendix No. 38.

ONUS OF MAINTENANCE FOR THE DIFFERENT SYSTEMS OF ELECTRIC TRACTION

	S.N.C.B. DC 3 kV	*Holland* DC 1.5 kV	*S.N.C.F.* DC 1.5 kV	*S.N.C.F.* AC 50 Hz	*S.B.B. C.F.F. F.F.S.* AC 16.66 Hz	*B.L.S.* AC 16.66 Hz
Traffic in millions of trail. gross. t/km . .	2 475.854	4 881.26	19.592	7 249.88	17 570.14	851.26
Consumption kW-h (energy for traction)	74 328 369	450 000 000	514 000 000	160 000 000	960 000 000	39 494 625
Power plants					794 000	
High voltage lines system		254 000	162 600		777 000	2 000
Substations	360 000	905 000	2 930 000	271 000	892 000	15 000
Overhead supply syst.	478 000	2 340 000	4 280 000	1 845 000	5 000 000	370 000
Total fixed installations	838 000	3 499 000	7 372 600	2 116 000	7 463 000	387 000
Cost fixed installations for every 1 000 kW-h	11.29	7.78	14.35	13.20	7.77	9.90
Cost fixed installations for every 1 000 000 trail. gross. t/km . .	338 (22.75 % of the total)	778	377 (28.5 % of the total)	292 (35 % of the total)	425	454 (2.3 % of the total)
Rolling stock	2 850 000	no data	18 600 000	3 960 000	no data	2 500 000
Cost of rolling stock for every 1 000 000 trail. gross. t/km . .	1 150 (77.25 % of the total)		950 (71.5 % of the total)	545 (65 % of the total)		2 935 (97.7 % of the total)
Total maintenance cost for every 1 000 000 trail. gross. t/km . .	1 488		1 327	837		3 389
Staff drivers	1 790 000		2 200 000	3 580 000		2 420 000
Cost of staff drivers for each 1 000 000 trail. gross. t/km . .	725		622	494		2 845

Appendix No. 39.

CONSUMPTION OF ELECTRIC ENERGY PER NETT TON KM ON THE VARIOUS RAILWAY SYSTEMS EXAMINED IN THIS REPORT

a) *Annual consumption kW-h per gross ton km*

Belgium (3 000 V DC) (11)

$$\frac{74\,328\,369}{1\,538\,371\,000 + 1\,113\,154\,000} = 0.028$$

Spain

a) Madrid — Segovia (1 500 V DC)

$$\frac{57\,529\,719}{2\,395\,112\,436 + 862\,538\,053} = 0.017$$

b) Ujô — Busdongo (3 000 V DC)

$$\frac{16\,030\,828}{57\,745\,764 + 151\,223\,640} = 0.076$$

France no details available

Morocco no details available

Italy (3 000 V DC) (4)

$$\frac{1\,477\,975\,000}{31\,098\,590\,200 + 34\,247\,734\,700} = 0.022$$

Holland (1 500 V DC) (2)

$$\frac{450\,000\,000}{1\,752\,448\,567 + 3\,906\,710\,378} = 0.079$$

Switzerland (16.66-cycle AC)

$$\left.\begin{array}{l} \text{Federal} = 0.054 \\ \text{Bernese} = 0.046 \end{array}\right\} \text{See other table}$$

b) *Annual consumption kW-h per nett. ton km, freight and passenger*

Germany

Belgium (3 000 V DC) (11)

$$\frac{74\,328\,369}{1\,463\,343\,000 + 1\,012\,511\,000} = 0.03\ \frac{\text{kW}}{\text{nett. t/km}}$$

Bas Congo no details available

Spain

a) Madrid — Segovia (1 500 V DC)

$$\frac{57\,529\,719}{401\,229\,800 + 705\,142\,500} = 0.051$$

b) Ujó — Busdongo (3 000 V DC)

$$\frac{16\ 030\ 828}{44\ 998\ 300 + 150\ 817\ 300} = 0.081$$

c) Leon — Ponferrada no details available

France

a) Paris — Lyon (1 500 V DC)

$$\frac{407\ 000\ 000}{6\ 270\ 618\ 000 + 9\ 234\ 058\ 000} = 0.026$$

b) Paris — Le Mans (1 500 V DC)

$$\frac{107\ 000\ 000}{1\ 659\ 000\ 000 + 2\ 428\ 000\ 000} = 0.026$$

c) total *a* and *b)*

$$\frac{514\ 000\ 000}{19\ 592\ 000\ 000} = 0.026$$

d) Valenciennes — Thionville (50-cycle AC) (3)

$$\frac{160\ 000\ 000}{390\ 000\ 000 + 6\ 859\ 878\ 000} = 0.022$$

Morocco (3 000 V DC)

$$\frac{74\ 920\ 440}{484\ 283\ 000 + 2\ 339\ 940\ 000} = 0.026$$

Italy (3 000 V DC)

$$\frac{1\ 477\ 975\ 000}{22\ 280\ 207\ 100 + 26\ 706\ 667\ 500} = 0.030$$

Holland (1 500 V DC)

$$\frac{450\ 000\ 000}{1\ 420\ 581\ 161 + 3\ 460\ 692\ 314} = 0.092$$

Switzerland

Swiss Federal Railways (50-cycle AC)

$$\frac{960\ 000\ 000}{\underset{(12)}{10\ 570\ 352\ 791} + \underset{(12)}{6\ 999\ 790\ 293}} = 0.054$$

(12) refers to gross ton/km, per annum

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$$\frac{39\ 494\ 625}{\underset{(12)}{490\ 056\ 576} + \underset{(12)}{361\ 206\ 229}} = 0.046$$

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